REPORT

OF

Committee in Charge of Experiment Station

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

FOR THE

Year Ending September 30, 1922

Printed by
Honolulu Star-Bulletin, Ltd.
1922

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Report of Committee in Charge of the Experiment Station

Honolulu, T. H., November 2, 1922.

To the President and Members of the
Hawaiian Sugar Planters' Association,
Honolulu, T. H.

GENTLEMEN: The Report of the Director of the Experiment Station covers in detail the work which is now being carried on by the different departments and which has been accomplished during the past year, and is herewith submitted for your consideration.

We would call your attention to the points brought out by Mr. Agee in a discussion of the Essential Factors Which Govern the Production of Sugar Cane, and, more especially, Their Relation to Each Other. This is surely a novel way of presenting these known factors. Making due allowances for variations in climatic and soil conditions, the deductions are logical and worthy of careful study and development.

The excellent work done in the Department of Entomology has been the means of preventing further outbreaks of the leaf hopper. The cane borer remains under the control of the tachinid fly, while the scolia wasp has so reduced the anomala beetle that further loss by this pest is very improbable. In some districts, considerable loss has been sustained due to the destruction of seed cane by the wire worm. Up to the present time, the attempts to locate and introduce natural enemies of the wire worm have not been successful, but search is being continued. Mr. Williams is now in Ecuador for this purpose.

The work of Dr. Lyon and Dr. Kunkel has demonstrated that the mosaic, or yellow stripe disease, is spread not only through heredity but also by the corn aphis. With this definite knowledge at hand, it becomes possible to control by various means the spreading of this disease.

Further study of conditions causing root rot, formerly known as Lahaina disease, by Messrs. Kunkel, Swezey, Pemberton, Carpenter and Stewart, has brought out interesting developments which will be a great aid in solving the cause or causes of this disease.

Mr. Pemberton has been co-operating with the Honokaa Sugar Company in studying effective methods of rat control. His report on this subject would indicate that the methods which have been developed by Mr. Naquin, manager of Honokaa Plantation, are proving very effective and economical. Rat elimination is not only highly desirable on account of the loss of cane due to this pest, but it is also absolutely necessary in the Hamakua district on account of bubonic plague infection.

Mr. Verret, in reviewing the work of the Department of Agriculture, lays special stress upon two most important points in field operations. First: fertilizing at the proper time; second: getting the cane to the mill and crushed as soon as possible after burning and/or cutting. Both points are well known to plantation men, but, unfortunately, are not followed up as carefully as they should be.

The work of improvement of sugar cane through bud selection, under the direction of Dr. A. D. Shamel, has made good progress during the past year and has been greatly assisted by the hearty co-operation of the plantations and their field staffs. We have been extremely fortunate in securing the services of Dr. Shamel to carry on the project next year.

Very promising work is being continued in seedling cane.

Mr. Verret also reports on the methods of operating and the results obtained at Waipio. The system of irrigation at Waipio, devised by Mr. Paris, is proving very satisfactory, and, doubtless, could be profitably adopted by plantations having similar conditions.

Mr. Kutsanai is successfully carrying on the work of the Manoa sub-station and is developing some seedling canes which are promising material for the extreme weather conditions in parts of Hawaii and Kauai.

Mr. McAllep and Mr. McCleery have carried on the usual factory inspections, which are of great practical value to the plantations. Other investigations have been carried on in regard to clarification, commercial value of last mill juice, quality of commercial sugar, and value of the upper joints of the cane.

Mr. Stewart has conducted several soil surveys of plantations during the past year, which will be of great value as basis information for further field tests in fertilization, irrigation, and varieties of canes to be grown. With the assistance of Mr. McGeorge, researches have been made on the behavior of Hawaiian soils under heavy fertilization, the effect of saline irrigation on soils, and the effect of borax on sugar cane.

The work of the Forestry Department, under the direction

of Dr. Lyon, and ably assisted by Mr. L. W. Bryan on Hawaii, and Mr. George A. McEldowney on Oahu, has made excellent progress during the past year. With much of the necessary preliminary work, such as map-making, fencing, etc., now finished, with the introduction of the fig wasp, and the successful fertilization of the seeds of the Moreton Bay fig and the Port Jackson fig trees, and with the probability of being able to successfully sow this seed by means of airplanes, the outlook for rapid reforestation of many of the denuded lands is very promising. During the past year, 244,083 trees were distributed from the Vineyard Street Nursery.

The Pineapple Department, also in charge of Dr. Lyon, has had a very busy and profitable year. Its activities cover the raising of new and superior seedling varieties, the study of pineapple diseases, and problems pertaining to soil, fertilization, and pineapple growth.

On account of the unfavorable financial outlook for 1922, it became advisable to exercise every possible economy in conducting the Experiment Station work which would not seriously interfere with important projects under way. The scope of some investigations and experiments has been curtailed, and considerable control work in the laboratories has been dropped for the time being.

The total expenses of the Station for the fiscal year ending September 30, 1921, amounted to $245,380.58. For the fiscal year of 1922, $227,827.38 was expended.

The large amount of work which has been accomplished by your Experiment Station is of inestimable value to the sugar industry of these islands. Great credit should be given to the Director of the Station, the heads of all the departments, and to each member of the staff, for it is only through the earnest and conscientious application of their knowledge that such valuable results are possible.

Respectfully submitted,

HORACE JOHNSON, *Chairman.*
Experiment Station Committee, H. S. P. A.

J. N. S. WILLIAMS, *Member.*
WILLIAM SEARBY, *Member.*
T. H. PETRIE, *Member.*
S. S. PECK, *Member.*

Director's Report

To the Experiment Station Committee,
Hawaiian Sugar Planters' Association,
Honolulu, T. H.

GENTLEMEN: The fiscal year, October 1, 1921, to September 30, 1922, has been an active one. The projects of the several departments have been carried forward to important results by O. H. Swezey, Frederick Muir, Dr. H. L. Lyon, J. A. Verret, W. R. McAllep, G. R. Stewart, and their associates and assistants.

There have been important developments in sugar cane pathology, entomology, agriculture, sugar technology, soil chemistry, forestry, and pineapple investigations.

The control of our principal insect pests has continued in the most satisfactory way and the rapid spread of the new leafhopper enemy offers probability that this pest will be held under still better control in the future.

Information of practical importance has been obtained on the cause and control of Yellow Stripe disease.

The work of the year has shown that root decay of sugar cane is, in part, an entomological problem and the fauna of the soil is being studied to find out what forms of life are contributing to crop injury.

The project of improving sugar cane through bud selection has progressed to a point where large numbers of plantations are working on this problem, and the promise of commercial benefit is becoming more definite as the work proceeds.

There are a large number of seedling canes which are showing up well in comparison with the standard varieties and there is little doubt but that some important additions to our present list of commercial varieties will result within a short time.

A great number of new trees imported into the Territory is resulting in a satisfactory outlook for reforestation, and tree planting operations are proceeding on various watersheds in a way that is encouraging.

Pineapple investigations have expanded and are now organized under the Pineapple Department.

The inspection of plantation factories has been continued. Some investigations on clarification and the profitable limits of extraction have given results of value.

Soil surveys are furnishing plantations with more exact information about their various fields and research work on soil problems is giving us more information about the properties of Hawaiian soils and their behavior under our present methods of agriculture.

Field experiments located throughout the Islands and handled jointly with the plantations continue to add information of value on methods of cultivation, fertilization, and cane varieties.

The last annual report of this Station contained a review of the results of ten years of experimental work dealing with the various subjects that pertain to increasing yields of sugar per acre.

Important findings bearing on a higher production of cane or sugar antedate the ten-year period that was under review. Perhaps no one who has followed the cooperative investigations of the plantations and the Experiment Station will question the fact that there is today a clearer understanding of the subject, and a great deal more precise information on many points that influence the yields of our fields than existed ten or fifteen years ago. It has been demonstrated repeatedly that yields of sugar cane can be improved by certain practical modifications of our agriculture.

What is the result when this information is drawn upon by the large group of plantations which are served by this Association?

A review of statistical records shows that here and there a field, an area of considerable size and commercial importance, responds to treatment in somewhat the same degree as the experimental areas. Here and there the yields of an entire plantation, in some cases groups of several plantations, show marked improvement over the yields of previous years.

Taking the Islands as a whole, what do we find? About 1907 the sugar area of this Territory assumed its present size of about 200,000 acres, or something more than 100,000 acres per crop. Studying the yields by five-year averages since then, we are confronted with these results:

TONS OF SUGAR PER ACRE—AVERAGED BY FIVE-YEAR PERIODS

	1907-1911	1912-1916	1917-1921
Oahu	6.520	6.255	6.422
Kauai	4.868	5.239	4.895
Maui	7.097	7.403	6.713
Hawaii	3.399	4.021	3.693
Territory	4.872	5.238	4.952

(The per-acre yield of the Territory advanced between the first five-year period and the second, and in the third five-year period fell back close to the level of the first five-year period. Of the individual islands, Kauai, Maui, and Hawaii each produced more per acre during the second five-year period than in the first, and less in the third than in the second. Oahu's per-acre yield drops between the first and second five-year period, and rises between the second and third, failing, however, in the third to reach the level of the first. In no case is the yield of the third five-year period higher than that of the first and that of the second as well.)

(The crop area advanced slightly for each five-year period: 106,093, 114,644, and 119,120 acres respectively for the first, second, and third period.)

Despite increased information as to how to produce better yields, these yields as a whole have not gone forward during the last five years.

Since 1906 the plantations have encountered a gradual change in the labor situation, which has had a definite bearing on all field operations. The circumstances incident to changing the cane varieties, and some other adverse conditions, have also had their effect. Our agriculture has been kept on a continuous one-crop system, without the benefits of rotation or fallowing in any great degree. All of this must be taken into consideration. Those who know the details of plantation difficulties may feel gratified that throughout this period the yields, taken as a whole, have been maintained at so high a level.

In all probability, however, a review of these yields can serve as something more than a source of gratification. The whole subject of past and future yields of our cane lands presents extremely interesting material for agricultural research. The essential factors governing sugar production are not as yet sufficiently understood *in their relation to each other.* In utilizing land, labor, water, fertilizers, and climate (temperature and growing-time), to produce sugar, we do not know in what proportion these agents can be combined to the best advantage. We do not know at what point some one of them becomes a limiting factor that holds down yields and causes any surplus of the other essentials to go for nothing.

To consider the interrelation of the several fundamentals or essentials of sugar production, we must express them in unit values so that they can be dealt with mathematically. So, instead of speaking of land, labor, water, fertilizers, and climate, we should convert them to acres, man-days of labor, million-gallons of water, pounds of nitrogen, etc. (Climate or growing-time may be handled according to the usual calendar divisions, day, month or year, and we may also have occasion to combine

area and time and, for this, to use the expressions acre-month, acre-day, etc.)

It is just as logical for a plantation to know to what extent its basic resources are to be drawn upon for each ton of sugar in every different field, as it is for a builder to know the number of units of cement, sand and rock that are to enter into each cubic yard of concrete for a certain piece of construction work.

The basic resources of a plantation, aside from suitable varieties of cane, and the control of pests and diseases, and the equipment necessary for a going organization are, we repeat:

Acres of land,
Man-days of labor,
Million-gallons of water,
Pounds of nitrogen (etc., etc.),
Months of growing-time.

A consideration of the possibilities of a more profitable use of growing-time would extend this discussion beyond the limits to be given it in this report. For brevity we will omit further reference to this essential here.

Fertilizers, dependent as we are upon them, can be drawn without limit from the world markets and are not apt to become limiting factors, except under extraordinary circumstances. They have an all-important bearing on the proposed research, however, in that they must be used in such proportion that we will obtain full value from labor and water and growing-time.

The following assumed values are representative of certain fields where irrigation is employed, the yield being 5 tons of sugar per acre:

0.2	acres	} = 1 ton of sugar.
15	man-days	
1,000,000	gallons of water	
25	lbs. of nitrogen	

Expressed on an acre basis:

1	acre	} = 5 tons of sugar.
75	man-days	
5,000,000	gallons of water	
125	lbs. of nitrogen	

If a change occurs in any one item, the proportions of all the rest, in relation to each ton of sugar produced, are altered thereby.

To illustrate clearly the mathematical relation between fundamentals of sugar production, we will take a simple example of area and labor in relation to yield and will show how an attempt to increase yields over a large area, having a limited labor supply, can operate against itself.

We will assume the case of 1,000 acres and an available labor supply of 75,000 man-days. We have been producing 5 tons of sugar per acre, which means that it has taken 15 man-days per ton. It takes, we will say, 5 man-days per ton of sugar for harvesting operations, and that leaves 10 man-days per ton of sugar, or 50 man-days per acre, for all field operations other than harvesting.

We will express this idea in tabular form:

Area	Sugar	Man-days total	Man-days harvesting	Man-days, other than harvesting
1,000 acres	5,000 tons	75,000	25,000	50,000
(1 acre)	(5 tons)	(75)	(25)	(50)

Now we will assume that through some improvement in agriculture it has been found possible to double the yields, to produce 10 tons per acre instead of 5. We are still dependent, however, upon the old ways of harvesting, so that for each gain of 1 ton of sugar we need 5 man-days of labor to harvest it. One thousand acres producing 10,000 tons of sugar would draw upon our 75,000 man-days of labor to the extent of 50,000 man-days. This would leave but 25,000 man-days to perform the work that 50,000 did before, so unless the improvements that could double the yield are accompanied by extraordinary means of saving labor, our attempt to increase the yield tends to defeat itself:

Area	Sugar	Man-days total	Man-days harvesting	Man-days, other than harvesting
1,000 acres	10,000 tons	75,000	50,000	(25,000) ?
(1 acre)	(10 tons)	(75) ?	(50)	(25) ?

Since it has been shown during the past few years that it is feasible to produce 15 tons of sugar on some areas of leeward Oahu, let us go further and see the result of attempting to increase the yield of our 1,000 acres to this amount. Instead of the original 5,000 tons of sugar we have 15,000 tons. Again each ton calls for 5 man-days for harvesting operations. Immediately we encounter the impossible, that of drawing 75,000 man-days for harvesting from an available supply of only that amount, thus leaving to ourselves the task of producing 15 tons of sugar without any labor for caretaking operations.

We may, therefore, ask if increased yields are dependent upon an increase in the labor supply or labor-saving developments? What has been said of the proposed great increases in yield is also true in degree of any increase at all. If the original yield of 5,000 tons were increased to 5,001 tons, we increase the necessary harvesting force from 25,000 to 25,005 man-days and reduce

the caretaking labor from 50,000 to 49,995. Our labor resources might be thought sufficiently elastic to take care of small increases in yield, but the yields of the Territory already given by five-year periods offer evidence to the contrary. Those figures show a decline in yield as we become better versed in how to improve our agriculture. Any increase in yield calls for more labor to harvest, and leaves less labor to produce the higher yield. Or, practically, if the yield of one field or group of fields goes up, it is in some degree at the expense of the yield on other areas.

Aside from increasing our total amount of labor and introducing labor-saving methods and devices, area reduction as a means of increasing yields offers the third opportunity for improving our sugar cane agriculture.

If, in the above hypothesis, where we attempted to increase the yield from 5 to 10 tons of sugar per acre, we had first made an estimate of the available labor supply in relation to this proposed increase, we would have found that we can proceed in increasing the yield from 5 to 10 tons of sugar per acre, provided we reduce the area from 1,000 to 750 acres. The total yield of sugar and the distribution of man-days under such a procedure is tabulated as under:

Area	Sugar	Man-days total	Man-days harvesting	Man-days, other than harvesting
750 acres	7,500 tons	75,000	37,500	37,500
(1 acre)	(10 tons)	(100)	(50)	(50)

It is thus seen, under this theory, with an available labor supply of 75,000 man-days, that we have the choice of producing 5,000 tons of sugar on 1,000 acres of land as against that of producing 7,500 tons of sugar on 750 acres of land. The latter course will be decidedly more profitable.

Without going into the details of the comparative profits at this time, we will entertain the possibility of increasing yields from 5 tons of sugar to 15 tons of sugar. The output in sugar and the distribution in our labor resources under this hypothesis is shown as under:

Area	Sugar	Man-days total	Man-days harvesting	Man-days, other than harvesting
600 acres	9,000 tons	75,000	45,000	30,000
(1 acre)	(15 tons)	(125)	(75)	(50)

It therefore appears that where climatic advantages permit of yields of 10 to 15 tons per acre, such yields should be produced, and that the obstacles in the form of a lack of available labor

supply or insufficient water should be met by appropriate reductions in the area under cultivation.

(One may argue that in order to thus increase the yields, the labor supply for operations other than the harvesting must be increased beyond the quota employed when the lower yield is produced. To what extent this is true remains to be shown in practice. Our work at Waipio does not show need for more labor in this direction. Granting that under certain circumstances more labor will be required, it is clear that it will not take more labor in proportion to the amount that the yield is increased. If we wish to increase the quota of 50 to 60 or 65 man-days per acre for operations other than harvesting, we are at liberty to do so and to introduce this consideration into our calculation to determine the appropriate reduction in area.)

This presentation of the subject of the relation between area and labor resources encounters more involved computations when we expand the idea to meet all of the existing conditions of practice. In the first place, from the standpoint of any one plantation, the labor supply is not a fixed and immutable commodity. In the second place, we cannot set about plans to increase yields by large percentages until we first have demonstrated what our fields are capable of producing. On the other hand, we must consider that any area averaging a certain yield contains portions which give lower yields than the average. And in reducing an area from 1,000 to 750 or 600 acres, one would, of course, drop the weaker acres and retain the better ones.

Whatever may be said of the deficiencies of this idea, in its present stage of development, as a working plan for governing plantation field policies, little can be said against the fact that it offers an interesting field of study. It is in this light that we wish to present it, and to propose as a part of the program of work of the Experiment Station a project dealing with the essential factors of sugar production in their relation to plantation field operations.

Preliminary inquiries into the matter have indicated that there are certain mathematical interrelations between areas, labor, water, and growing-time—the raw materials that go to make sugar—which can be determined and used. If we overlook these values, they operate to our detriment; if we make our work conform with them, we do so to our own advantage. We admit the truth of this for the materials of engineering. We are probably to learn that it is likewise true in agriculutre.

This being the case, we can anticipate the time when our field operations will be planned on the basis of estimates which shall

include not only the financial expenditures predicted for the crop, as is the case today, but we will also take measure of the extent to which each field and each estimated ton of sugar in that field shall draw upon the basic resources which are at the command of the plantation. These estimates will lead to decisions as to how man-days of labor, million-gallons of water, pounds of nitrogen, etc., can be combined in practice to the best interests of the plantation.

Where climatic conditions do not permit of high yields, these calculations will take a different form, just as our improvements in agriculture must take a different form under such circumstances. If the adversities of climate prevent the consideration of more than four tons of sugar to an acre with any degree of safety, we then become interested, not in intensifying in the direction of high yields per acre, but in providing for high yields per unit of the expensive-factor-of-production. On the unirrigated plantation this is labor.

The developments of the past year or two on Kauai offer striking examples of agriculture intensified in the direction of yield per man-day, rather than yield per acre. At Kilauea, automatic irrigation causes one man-day of labor to perform the work of 20. At Grove Farm there is a newly designed planting equipment followed by a soil scarifying device that literally prevents weed growth, with all the advantages usually associated with the ounce of prevention vs. the pound of cure. On Maui, a new departure in irrigation economizes on both water and labor to a degree that has heretofore been thought impossible. On Hawaii, we find interest being taken in the use of hardy varieties of cane, that ratoon readily and require a minimum of cultivation. Paper mulching offers another means of increasing the value of the man-day.

The conditions under which we operate must determine the character of the possible improvement in agriculture. Generally speaking, however, it will be found that the most economical crop to grow is the one which has been allowed to take reasonable advantage of its climatic environment. High yields per acre will often, but not always, be high yields per man-day and per million-gallons of irrigation water.

Under leeward, irrigated conditions, with a warm climate, the most profitable sugar production is apt to be found in high yields per acre, even when these are to be attained at a sacrifice in area in order to have sufficient irrigation water and labor. In the cooler, humid districts, the most profitable sugar production is

apt to be that which is based upon the yield per man-day, even where this calls for an appropriate sacrifice in yield per acre.

Sacrifices of this sort are to be carefully balanced against the gains that result from them, and thereby sugar production tends to become less a matter of opinion and more a question of mathematics, in the choice of methods and field policies.

The progress of the work of the past year is given in the following paragraphs:

The Leafhopper

There have been no serious outbreaks of leafhopper during the past year. The principal development in the control of this pest has been the rapid spread of its natural enemy, *Cyrtorhinus mundulus,* introduced from Australia by Mr. Muir in 1920. An account of the leafhopper situation is given by Mr. Swezey as follows:

The leafhopper has been generally very scarce, in most of the plantations difficult to find. In a few places they appeared to be on the increase for a time, but were soon under control again. The egg-parasites which have been the chief factor in control have apparently been sufficiently effective. Their presence has always been ascertained in any examination of leafhopper conditions. Even in cases of extreme scarcity of leafhoppers, if any eggs were to be found, some of them were parasitized, and usually a good proportion of them, both of the egg-parasites usually having a share. Sometimes *Paranagrus* was the most effective, and sometimes *Ootetrastichus* was found the most effective. In the many examinations made in the various plantations, the parasitism by *Paranagrus* has usually ranged between 20 per cent and 65 per cent, with extremes of 2 per cent minimum and 94 per cent maximum. The parasitism by *Ootetrastichus* has usually ranged between 10 per cent and 50 per cent, with extremes of 4 per cent minimum and 65 per cent maximum. The total parasitism by both parasites has ranged between 9 per cent and 94 per cent, in most instances being above 60 per cent and from that to 75 per cent.

A promising factor in the control of the leafhopper has been the *Cyrtorhinus* bug. It increased remarkably in a few places where there were sufficient leafhopper eggs for it to thrive on. The greatest abundance observed was at Ewa Plantation and at Mountain View of Olaa Sugar Company. From 20 to 40 of the young red bugs could be seen per stalk of cane. On Hawaii, no attempt was made to spread this bug to other parts of the island on account of the scarcity of the leafhopper in most of the plantations; but it has become widely dispersed of itself, from Olaa Sugar Company where the original colonies were liberated. During the year it has been found as far as Pepeekeo and Honomu on the Hilo side; at Halawa and Union Mill in Kohala; and at Hutchinson Plantation in Kau. In these places there were not sufficient leafhopper eggs for the bug to increase on. It is very marvelous that they should have become spread to these extremes and that they should be able to maintain their existence dependent as they are on the leafhopper eggs for food. On Oahu, besides at Ewa Plan-

tation, this bug is known to be established at Waialua, Waipio Substation, and Oahu Sugar Company. In the latter place they were widely dispersed, though very scarce on account of scarcity of leafhopper eggs. At Ewa Plantation, it was feared that they had died out the previous year, when the leafhopper became greatly reduced; but in March they were found to be exceedingly numerous in a field where leafhoppers had persisted for some time. From this field many thousands of the bugs were collected and distributed to other fields of the plantation wherever the leafhopper began to appear. A colony was taken to Waipio, where an outbreak of leafhopper had begun. The bugs increased there so as to be quite numerous before the leafhoppers had finally disappeared.

Mr. Swezey also deals with the question of the *Cyrtorhinus* interfering with the work of long established egg-parasites, saying that there is already some evidence of a reduction of the egg-parasites where the *Cyrtorhinus* is abundant. But he points out that we must now consider not the work of a single parasite alone, but the combined attack on the leafhopper by the egg-parasites and *Cyrtorhinus*. This subject was dealt with by Mr. Muir in 1920, and he gave his two answers to the questions he had himself proposed as to the possibility of *Cyrtorhinus* destroying *Paranagrus* and so doing more harm than good. It may be well to repeat here what Mr. Muir said then:

(1) If it were to entirely supplant it and was equally effective in destroying the eggs of *Perkinsiella* it would be a gain, as its ability to stand up against the heavy rains in certain districts would prevent some of our worst outbreaks.

(2) There is no reason to believe that it will supplant the *Paranagrus*, as it has not done so in Australia or Fiji. It will attack both parasitized and unparasitized eggs and the joint results will be a distinct benefit. For example,—if they both attack 80 per cent of the eggs, the results of *Paranagrus* alone would be for twenty hoppers and eighty parasites to hatch out of every 100 hopper eggs. If *Cyrtorhinus* was also acting along with *Paranagrus*, then the ultimate result would be four hoppers and sixteen *Paranagrus*, the same proportion but a vastly improved condition.

The Cane Borer

The situation with respect to the cane borer continues on the satisfactory basis of past years. The New Guinea Tachinid, introduced by Mr. Muir in 1910, continues to hold this pest under control. "Wherever any borer injury has been examined," says Mr. Swezey, "the presence of the parasites was noted, and usually it was found that a good percentage of the borers had been destroyed by them."

The Anomala Beetle

The *Anomala* beetle, which was put under control by the *Scolia* wasp which Mr. Muir found in the Philippines in 1915, is now

so completely held in check that the damage which it does is negligible. The small increase in the number of grubs to be found in one field on Oahu this year is of some technical interest, but of no commercial importance. From Mr. Swezey we gain the following account of the situation with respect to this pest on Oahu and the spread of the Scolia wasps to localities where they are thriving at the expense of the rose beetle *Adoretus:*

This pest has remained under control by the *Scolia* wasps as in the past few years since *Scolia* reached its maximum. Apparently, however, there was somewhat of an increase in *Anomala* in one field of the Oahu Sugar Company, for the grubs could be found this summer more readily than in the past two years. This was in a rather limited area of the field and they did not increase to injurious numbers. *Scolia* has been sufficiently abundant to prevent this, in fact they were more abundant than during the past two years in that particular region. It is likely that *Scolia* had become so much reduced by the scarcity of *Anomala* (though there were always *Adoretus* grubs on which they also breed) that it gave the *Anomala* a chance to increase, and this in turn has given the *Scolia* an opportunity to become abundant again. This illustrates what commonly takes place in insect control by parasites. There is the up and down, or increase and disappearance of the pest, according to changing circumstances, sometimes favoring the pest and sometimes the parasite. *Scolia* wasps were so numerous that during the summer, Mr. J. F. Illingworth collected many thousands and sent them to New Jersey, where the U. S. Bureau of Entomology was desirous of attempting their introduction to combat the green Japanese beetle which has become a very bad pest there in recent years. During the year, *Scolia* has been observed abundant in a number of places in the Islands, where it has had only *Adoretus* grubs to breed on, which indicates that it is having some effect on that bettle. They have not yet been observed abundant on the Island of Hawaii, however. For some reason they fail to thrive there.

Wireworms

After a thorough investigation of the possibilities of finding natural enemies of the wireworm in Australia and the Philippines, Mr. Pemberton and Dr. Williams have withdrawn from those fields and the search has been turned to those countries lying around the Gulf of Mexico.

Dr. Williams, after studying the insect collections at museums in Washington for possible clues, proceeded to Panama; from this place he wrote on September 20, 1922, that he had decided to leave Panama and go to Ecuador, where he would visit the sugar plantations along the railroad back of Guayaquil. "There seem to be few good accessible regions about Panama and no very high land," he writes. Of Ecuador he says, "The region is supposed to be cooler than at Panama and has adjoining high lands and large cane areas."

Mr. Pemberton has taken up work in the Hamakua district, where he is following the wireworm situation as well as other projects dealt with elsewhere in this report.

Mr. Swezey discusses the wireworm damage as follows:

Newly planted fields of D 1135 cane in the Hamakua district are still subject to severe injury to the seed by wireworms. The same kind of wireworms, though abundant in Kau, where Yellow Caledonia was planted, did not cause the same damage. Further trials of poisons, repellents and baits have been made, but none so far have proven practical for field use. At present the most promising means of avoiding wireworm injury is to plant some other variety than D 1135. Badila, Yellow Caledonia and Yellow Tip canes were found to not suffer the same injury from wireworms as does D 1135. If the latter cane must be planted, an extra amount of seed should be used so that there is more chance of enough escaping injury to provide for a satisfactory stand of cane, or to necessitate less replanting later on.

Mr. Pemberton found a fungus disease destroying some of the wireworms in Queensland. This was brought to Honolulu, and has been experimented with in the field with some success. A similar fungus disease, already here on *Adoretus* and *Anomala* grubs, has been found to occasionally destroy wireworms.

Minor Pests on Sugar Cane

The damage that aphids and mealybugs do to sugar cane has never been estimated in figures, but these no doubt make an annual toll upon our crop which is important. The introduction of the Australian Lacewing fly by Dr. Williams as an enemy on aphids, and the introduction of ladybeetles which feed upon sugar cane mealybugs, the latter through the work of Mr. Osborn in Mexico, will undoubtedly prove of value.

From Mr. Swezey's report we read:

Australian Lacewing Fly

This insect, *Micromus vinaceus*, introduced by Dr. Wililiams from Australia, as an enemy to plant lice, is now known to be widely established and abundant in places. During the year it has been found in such widely separated districts as Manoa and Opaeula on Oahu; the western part of Kauai; Hilo, Hamakua, and Kohala on Hawaii. This is a valuable addition to our list of natural enemies of plant lice.

Sugar Cane Mealybug Enemies

During the summer months, Mr. Osborn sent from Vera Cruz, Mexico, several species of ladybeetles and parasites of mealybugs. Some of these attack the cane mealybugs. The two kinds of ladybeetles are very small and well adapted for getting behind the leafsheaths and gaining access to the mealybugs. They are *Diomus* sp. and *Nephus* sp. A few hundred of these ladybeetles have been liberated in the cane plots at the Experiment Station and at the Manoa Substation.

The mealybug parasites were found working on the gray sugar cane

mealybug in Mexico, but here they have been bred on the pink sugar cane mealybug as well. About 200 of these parasites have been liberated in the cane plots as above.

Armyworms

The various cutworms, of which the armyworm is the chief offender, have never been under as complete control as we would like to have them. Acting on the suggestion of Mr. Swezey and Mr. Fullaway, arrangements have been made whereby Mr. Osborn, who has been in Mexico in connection with the work of the Board of Agriculture and Forestry, will remain there for the purpose of searching for natural enemies of these pests. The damage that these cutworms do is dealt with by Mr. Swezey as follows:

There was an unusual prevalence of the armyworm, accompanied more or less by cutworms, during the spring months in many of the plantations of Hawaii. This was chiefly in mauka fields, more or less adjacent to extensive grass areas where the armyworm breeds continuously, and spreads to the cane fields. In many instances the infestation of cane fields was due to their grassy or weedy condition, where hoeing had been neglected, due to an insufficiency of labor. The young cane in both plant and ratoon fields was much eaten, leaves sometimes being entirely eaten from the young shoots, and consequently the fields receiving considerable setback. The introduced armyworm parasites (two Tachinid flies and two Ichneumon flies) seemed to be in their usual numbers, but even with the assistance of the ever-present mynah bird, they failed to control the armyworms. It is apparent that more parasites for armyworms are needed, and also more caterpillar-eating birds, whenever there is an opportunity of obtaining any of these. Until such are obtained, the most satisfactory way of combating armyworms is by the poisoned bran bait.* At Honokaa, it was found that bagasse could be substituted for the bran in this mixture.

A Java Leaf Mite

A leaf mite which has been present in Hawaiian cane fields for some years was recently recognized as species that occurs in Java. It is not anticipated that this will prove to be a serious pest. The situation is discussed by Mr. Swezey:

A considerable area of young plant cane in several fields of Oahu Sugar Company was infested in the late summer by a mite occurring

* Usual formula: 5 lbs. bran,
¼ lb. Paris green or white arsenic,
1 pt. cheap molasses,
1 lemon or orange,
1 gal. water.

on the underside of the leaves. These were in such numbers as to produce noticeable injury to the cane. The leaves at first turned yellowish in longitudinal streaks; then reddish; and finally drying up and dying sooner than they otherwise would. Infestations by mites have been noted before on cane leaves at times and places, but of no special consequence, and the species of mite was not determined. In the present instance, the mite is determined as the same species which occurs on cane leaves in Java (*Tetranychus exsiccator*). This will apparently be the first definite record of the occurrence of this species of mite in the Hawaiian Islands. Larvae and adults of a small black ladybeetle were found feeding on the mites. Larvae and adults of a minute Staphilinid bettle were also found feeding on them and their eggs. Another mite occurring on the leaves was apparently a predacious species, though not actually observed feeding on the leaf mites. The outcome of this infestation will be watched with special reference to its seriousness. So far it seems to be on a par with the periodical infestations by the cane aphis, which are temporary and of little consequence. Experiments with nico-sulphur-dust are being tried as a remedy.

Mosaic or Yellow Stripe Disease

The Mosaic or Yellow Stripe disease, which has been recognized since 1911 as a source of serious loss in our fields and a possible menace of much greater proportions, has, through investigations of the past year or two, been put upon a different status. The work of Dr. Lyon and Dr. L. O. Kunkel has shown us that this disease is spread not only through heredity by means of planting diseased seed cane, but that it is also carried by the corn aphis, and that furthermore this insect transmits this disease from certain other plants to sugar cane. It therefore becomes possible to control the disease through the following procedures:

1. By planting fields with seed cane from healthy plants.
2. By the suppression of weeds capable of harboring the disease.
3. By the suppression of the corn aphis by natural enemies which are already here, or by others which it may be possible to introduce.
4. By destroying diseased cane plants which may appear accidentally notwithstanding the foregoing precautions.
5. By the utilization of resistant varieties where the surrounding territory cannot be freed from the disease.
6. By the propagation of seedlings which shall be resistant or immune to the disease.
7. By the prevention, through quarantine measures, of the introduction into the Territory of other insects which may be capable of spreading the disease in the same way the corn aphis does.

Dr. Lyon gives the following account of the investigations on the Mosaic or Yellow Stripe disease problem:

Dr. Kunkel has made noteworthy progress in his investigations of Mosaic during the past twelve months. His researches are providing us with a knowledge of the cause of this malady and the means by which it is spread from plant to plant in our fields. This information will enable use to restrict the occurrence and spread of the disease by taking effective measures against the factors which bring about its distribution.

Dr. Kunkel has found Mosaic on numerous cultivated grasses including corn, sorghum, Sudan grass, Tunis grass, Guatemala grass and Wonder Forage grass; also on Goose grass and Bristly Fox Tail grass, which are very common weeds in our cane fields. We have reason to believe that one and the same disease attacks all of these grasses and sugar cane. In his experiments, Dr. Kunkel has actually transferred the disease from Sudan grass to sugar cane and from Sudan grass to Bristly Fox Tail grass. Strong evidence is also available that the disease has been transferred from sugar cane to both corn and sorghum. In his experiments on the transferring of the disease from sugar cane to sugar cane and from other plants to sugar cane, Dr. Kunkel has been able to find but a single natural agent which brings about this transfer, this agent being the corn aphid. This insect does not feed upon the sugar cane plant by choice, but thrives on all of the other cultivated grasses mentioned above. It would seem, therefore, that a great deal can be accomplished towards the restriction of Mosaic in our cane fields by limiting the cultivation of other grasses in their neighborhood and by the elimination of all weedy grasses.

Any other measures which will tend to reduce the corn aphid population in and about our cane fields should likewise limit the spread of Mosaic among our canes.

Dr. Kunkel has also demonstrated in his experiments that the Mosaic of sugar cane can be transmitted from diseased to healthy plants by inoculating the latter with juice extracted from the former.

During the fall of 1920, Dr. Kunkel installed four separate experiments on as many plantations, these experiments being designed to determine the relative yields obtained when cuttings from healthy canes were planted in competition with cuttings from canes having Mosaic. These experiments were harvested during the past summer and the results obtained from three are given below:

IN FIELD 40 OF HONOLULU PLANTATION

Variety—	Average Yield per Stool from Healthy Cuttings	Diseased Cuttings
Badilla	45.5 pounds	9.9 pounds
D 1135	45.0 "	25.2 "
Striped Tip	44.8 "	7.8 "
H 109	43.6 "	27.7 "
Lahaina	37.0 "	11.5 "

IN FIELD GAY-3B OF WAIALUA AGRICULTURAL COMPANY

Variety—	Average Yield per Stool from Healthy Cuttings	Diseased Cuttings
H 109	77.6 pounds	48.4 pounds
Yellow Caledonia	71.7 "	20.5 "
D 117	68.2 "	55.1 "
D 1135	64.3 "	44.0 "
Lahaina	49.1 "	35.7 "

IN FIELD H OF HAWAIIAN COMMERCIAL AND SUGAR COMPANY

Variety—	Average Yield per Stool from Healthy Cuttings	Diseased Cuttings
Yellow Caledonia	91 pounds	3 pounds
D 117	83 "	17 "
D 1135	81 "	42 "
H 109	80 "	29 "
Striped Tip	73 "	26 "
Lahaina	48 "	12 "

During the early growth of the cane planted at Waialua, the disease spread very rapidly to the stools springing from healthy cuttings and when the experiment was harvested, very few stools in the block were quite free from the disease. The results obtained in these experiments prove beyond a doubt that none of our standard canes can carry Mosaic without suffering serious injury with a corresponding loss in sugar production.

In his laboratory studies, Dr. Kunkel has, in recent months, demonstrated foreign intracellular bodies in the diseased tissues of cane afflicted with Mosaic. He had previously demonstrated similar bodies in the diseased tissues of corn, Chinese cabbage and Hippeastrum, and held that they represent a stage in the life history of the agent causing the disease in these plants. In the cane plant, these bodies are to be found in necrotic areas only a short distance below the growing point and they become obscured at an early stage in the development of the cane tissues through the breaking down of the cells in which they lie. It becomes impossible, therefore, to demonstrate them in the older tissues of the cane plant.

In some recent experiments, Dr. Kunkel has found "that when the very young leaves of diseased cane are exposed to bright sunlight, through the removal of the older leaves, they develop a solid green color and show no evidence of Mosaic. It is believed that the light kills the causative agent and thus prevents its development. It is well known that old leaves partially recover from the disease. The experiment suggests that this may be due to their exposure to light."

As a result of these observations, we are testing the effect upon the causative agent of various exposures to X-rays. We are able to follow this line of experimentation through the courtesy and co-operation of Dr. H. L. Arnold of The Clinic. These experiments have not been carried far enough as yet to permit of any deductions or conclusions.

Root-Rot of Sugar Cane

Root-rot is the designation given an unhealthy condition of the sugar cane plant, which manifests itself through a depleted root system. It may be one disease or several. It is the malady which formerly went under the name of Lahaina disease. That trouble, from a practical viewpoint, was resisted in the leeward irrigated districts by such canes as H 109, Yellow Caledonia, and D 1135. The term Root-rot also includes the situation upon Kauai and elsewhere where the Yellow Caledonia fails to ratoon in a thrifty way, but where the variety D 1135 shows ability to meet the situation. The term likewise covers the diseased condition of cane roots in the upper lands of Hamakua. Here the D 1135 fails to show the resistance it does elsewhere.

Root-rot therefore is a condition which affects a wide range of conditions and a wide range of varieties. When we speak of immunity or resistance to it, the words can be used only in a relative sense, as it is not unlikely that injury to cane roots occurs in some degree in most, if not all, of our fields.

Important developments have been made during the year offering suggestions for investigations that promise to be important. Dr. Kunkel, in examining canes in the upper lands of Hamakua and fields of windward Kauai, found small holes in the surface tissue of the roots, apparently caused by some form of insect life. The problem thus entered the field of entomology. Through the investigations of Mr. Swezey it was shown that the roots of sugar cane have many factors of injury throughout all of the cane-growing districts. He found that cane roots were gnawed to some extent by three kinds of minute subterranean snails and several kinds of sowbugs. A mite, similar to one which is known to injure grape roots in France, was found by Mr. Pemberton to do injury to cane. It was in an investigation pertaining to this mite injury that Mr. Pemberton found at Honokaa another offender, a slender, active centipede. He has now established very definite proof that this centipede is responsible for the cane injury originally noted by by Dr. Kunkel. These wounds are looked upon by Dr. Kunkel as a means of infection by fungi which cause the roots of the sugar cane to decay. The centipede found by Mr. Pemberton has been determined by Mr. R. V. Chamberlain, of the Museum of Comparative Zoölogy, Cambridge, Massachusetts, to be *Mecistocephalus maxillaris*. "It is a member of a carnivorous family," states Mr. Swezey, "and has not been known as a vegetable feeder. But here there seems to

be more proof of its being responsible for this kind of root injury than the other animals mentioned."

The extent to which this centipede will be found throughout the various districts where Root-rot has occurred on different varieties, is yet a matter to be determined.

Concerning his investigations at Honokaa Mr. Pemberton says:

After considerable experiment with a number of different soil organisms, together with a study of cane roots in the field, I have finally isolated a small thread-like centipede (one of the commonest organisms in the cane stools here), and have been able to secure the typical root-hole injury, under recent discussion at the Station, by inserting this centipede in sterile soil in which sound cane roots have been placed.

I first suspected it as the organism responsible for the root-injury, upon breaking open a clod of earth in which a cane root had penetrated and exposing the root without jarring or disturbing anything on it. Here, near the tender end, I found one of the small centipedes lying, with its head close to a fresh hole in the root. A small stool of cane in the same field was then dug up, with about three cubic feet of soil which completely surrounded it. This was brought from the field and carefully examined. In two days' time every minute particle of the soil and each root was examined under a hand lens. From this material two sowbugs were taken near the surface, five small soft-bodied Thysanurans, four earthworms, two mites of the family Parasitidæ, well in the soil and very minute, and forty-eight of the young centipedes under discussion. The roots were badly punctured with small holes and gashes. This still further confirmed my suspicions that the centipede was responsible for the injury. Stools were then examined over many parts of the plantation, all the way from near the sea to the top fields. Wherever the root-injury was common, the centipede could be easily found. Where it was uncommon, it was difficult to find the organism. I have failed to find it at all in one or two stools showing only one or two punctures in the whole root-system. If they were there, I missed them. The young are very small, as fine as a thread, quite active and able to penetrate soil very rapidly.

I have been able to find the centipede herein discussed most numerous in ratoons, particularly Caledonia cane. In such cane the root-injury is sometimes very bad. Where roots have nearly all died away, the centipedes are not so common. They may perhaps leave stools at such a time and permit a partial recovery. This is only surmise, however. It all needs a very careful and prolonged study.

None of this root-perforation can be found in grasses or weeds growing in the cane fields or apart from them. The centipedes are present, however, but not common, in fallow fields and grassy, uncultivated land.

In bring his work on Root-rot to a close, C. W. Carpenter felt that the evidence he had accumulated in his work at this Station continued to support his earlier deductions. He summarized his investigations in writing:

I am more convinced than ever that *Pythium* is an important factor in producing the condition we know as Root-rot or Lahaina disease. That other fungi or organisms may contribute to the same end is not to be overlooked, but I have not succeeded in obtaining positive evidence of the causal relation of such fungi as *Rhizoctonia*, *Fusarium*, etc., to the disease.

Experiments on the control of Root-rot in the field, both with cane and pineapples, by means of chemical applications to the soil, have shown nothing of promise. With cane absolutely no deductions could be made from the appearance of the cane until it got too large for examination. . . . .

The large cement tub experiment has shown very definitely that Lahaina cane in "sick" Waipio soil germinates poorly and grows much less vigorously than in the same soil steam sterilized under 25 lbs. pressure.

Inoculation of steam sterilized "sick" soil in these large pots with *Pythium* has shown no effect on the plants to date. As this has been favorable growing weather, results may possibly show up later when, as we know, the weather conditions are less favorable to cane and more favorable to the Root-rot.

The relation of various forms of animal life to the appearance of root decay in sugar cane introduces a factor which has thus far not been incorporated in any inoculation experiments with fungus cultures. And when the cause (or causes) of this diseased condition of cane is finally known, it may be found that it is actually due, as per the present theory, to the combined attack of animal life and vegetable fungi, the first making the root injuries, through which the others gain entrance to the root tissues.

That the whole matter of root decay is intimately connected, in a practical way, with weather conditions and relative resistance of cane varieties under different conditions of climate and soil, there is no doubt. The whole question depends, from the standpoint of crops, upon whether the cane can put forth roots fast enough to withstand the various agencies that cause them to decay.

Mr. Stewart, investigating the trouble on Kauai, found no chemical fault of the soil which could explain the poor growth of the ratoons, and his observations support what has been said on the subject of the influence of climate and varietal resistance. His report reads in part:

The root trouble was most prevalent in the coolest fields, and was especially evident during the period of lowest temperature, which continued longer than usual during the past winter. Our preliminary observations indicated that the difficulty was partly due to the lack of vitality of the Yellow Caledonia cane under the conditions prevailing in portions of Kauai.

A second visit was made to Kauai in late July, some three months after the first investigation. All the fields previously studied were again examined as well as the ratoon fields which had been harvested since my first visit. I found nearly all the younger backward Caledonia ratoons were now making a fair growth. Adjacent fields of Caledonia harvested later, during warm weather, had shown no signs of root-rot and were in many cases further advanced than the cane which had been cut months before. Some of the older ratoons of 1923 crop cane, which had been badly stunted by root-rot, had made little improvement. It will be important to note whether the young fields which suffered from root-rot last winter will again be affected when cool weather sets in.

For the sake of comparison, examinations were made of the condition of the Yellow Caledonia ratoons at Kekaha, Hawaiian Sugar Company, and McBryde Sugar Company. All of these plantations are located on the warm lee side of Kauai. At Kekaha and Hawaiian Sugar Company the root growth of the Caledonia ratoons is fully as vigorous as that of the plant cane in the cooler districts. No difficulty has ever been noted in the ratooning of this variety of cane. At McBryde, Caledonia in general makes a good growth in the ratoon fields, but one field of second ratoons, cut in cool weather, rotted out completely soon after it was harvested. This furnished further evidence that the root-rot trouble is favored by damp, unfavorable growing conditions and disappears with warmth and sunlight.

I found Kilauea, Grove Farm, and Lihue have each developed planting machines which satisfactorily solve the problem of putting in a larger area of plant cane each year. This will decrease the root trouble with Caledonia for a time, but should it become more acute, the need of a new vigorous variety will become very pressing.

With many new seedlings being tried at various places on windward Kauai at this time, there is promise that a vigorous cane will be found.

Other Cane Diseases

Dr. Lyon has furnished an account of observations on three other diseases of the cane plant. The one which is reported as a new disease was confined to a fraction of an acre. The leaf disease of Tip canes in Kohala deserves further study before predictions can be made as to its potentialities for harm. Fiji disease is the malady which has not appeared in Hawaii. It was studied in Fiji by Dr. Lyon in 1911, who reported the control measure employed—the selection of planting material from cane stools which show no trace of the malady.

Dr. Lyon's report on these subjects reads:

A New Cane Disease

A disease which is quite new to our experience has appeared in H 109 cane in a small field (14B) in the bottom of a gulch on Oahu Plantation. Plants affected by this malady are conspicuously stunted,

while their outer leaves turn yellow and die. In general appearance, the diseased plants simulate cases of Root-rot or Lahaina disease, but an examination of their root-systems shows that the latter are in comparatively sound condition. When the young stalks are split lengthwise, it is found that the internal tissues in their lower portions are very much darker than normal. Microscopic and cultural examinations of these darkened tissues show that they are occupied by numerous bacteria and fungi. The tissues from a corresponding position in healthy plants are nearly white and quite free from organisms. It would appear, therefore, that this new disease is induced by microorganisms which invade the tissues of the stem. Several organisms appear to be present in every stem examined, but a bacterium which forms yellow colonies appears to be present in every case and, consequently, is most apt to be the primary cause of the trouble.

A Leaf Disease of the Tip Canes

A disease attacking the leaves of the Tip canes is gaining headway in the Kohala district. The first symptoms to be noted on an affected shoot are purple streaks on the leaf blades, these streaks following the veins and, consequently, diverging from the mid-rib. These streaks usually appear first on the older leaves and near the juncture of the blade and sheath. From this point, they extend upward into the blade and downward into the sheath. The infection progresses from the older leaves to the younger leaves and, in some cases, through the spindle, bringing about the destruction of the latter. Careful studies of diseased shoots indicate that the malady is due to parasitic bacteria. This disease was first noted about two years ago in mauka fields in the Kohala district, but since that time it has spread to all parts of the district, limiting its attention, however, to the Tip canes.

Fiji Disease

Dr. Kunkel has completed his cytological studies of the pathological tissue of canes suffering from Fiji disease. He has compiled a short paper setting forth his observations, which is now ready for publication. His work brings forward additional evidence that the galls, characteristic of Fiji disease, are induced by a parasitic organism.

The Control of the Field Rat

Human enterprise, in all its phases, and human negligence have disturbed the balance of Nature in favor of these species, have afforded them an unnatural degree of protection from their many enemies, a large and unmerited share of the world's foodstuffs, together with perfect traveling facilities. Small wonder, then, that these creatures have invaded and colonized all lands . . . . . that they have developed into serious pests, taking heavy toll from human prosperity, and forming a most deadly menace to the public health.

Thus writes M. A. C. Hinton in "Rats and Mice as Enemies of Mankind," a publication of the British Musuem. That authority held that the world should set itself to the task of devising means for the extermination or control of these rodents. He

discusses the difficulties of the undertaking, but advocates that these should not stand in the way of organized research and effort to an end so much to be desired, for ". . . the rat problem is as serious and urgent as any before the public at present. Whatever the cost in labor or money may be, the extermination of the rat is a necessary step for public safety."

In Hawaii we best know the seriousness of the rat problem, through the dissemination of bubonic plague and the great destruction of growing sugar cane. The obstacles to rat control in some districts have appeared prohibitive. The difficulties of coping with an infestation covering thousands of acres of cultivated fields and waste lands seemed insurmountable. Anything approaching adequate control, it was thought, could not be accomplished at an expense that would be within reason.

After the work of the past year by the Honokaa Sugar Company and Pacific Sugar Mill, our viewpoint on the situation is changing. Mr. Pemberton, of this Station, who has been coöperating with Mr. Naquin and his staff at the plantations, gives the following summary of the information he has obtained during the past few months on the operations against rats at those places, where a new system of poison baiting shows amazing possibilities:

Trapping for field control has been found very unsatisfactory. During the years 1915 to 1918 inclusive, a total of 268,761 rats were trapped, at an expense of $40,672. There has been no yearly decrease in rat-eaten cane and certainly no decrease in the number of rats the trappers have been able to catch. During 1919-20 the catch each year was nearly double that of the preceding years, for during those two years, 105,000 rats were actually caught, and yet I am told the rat injury to cane those years was as bad as ever. This is easily understood when it is realized that the area covered by the traps is only a "drop in the bucket" compared with the thousands of acres of untrapped land under cane. And even this amount of trapping is expensive. Trapping can be useful for only one purpose, where rats are so enormously abundant in Hamakua. It greatly assists the Health authorities in locating exact areas of bubonic plague infection. I believe the poison methods, as now developed at Honokaa, should be applied in all parts of Hamakua, most intensively, at all points where the Board of Health locates plague-infested rats and human cases of pleague. Trapping certainly cannot eliminate the source of infection thoroughly, while poisoning, as we understand its effect upon the rat population at Honokaa now, should finally achieve this end.

Data, which the Honokaa Sugar Company has given me, respecting the extent of actual rat-damage to cane are very complete and cover a number of years of careful study. This shows a loss of about $100,000 annually. Mr. Naquin has urged me to check this up in every way possible. I have been working on this and from final estimates fully agree with them on this point. During 1922 counts have

been made by responsible men at Honokaa and Kukuihaele of average cane in all harvested fields. In 39,200 sticks of cane examined, 29 per cent were found eaten more or less by rats. Chemical analyses of such eaten cane have definitely shown a heavy loss in purity of juices and weight of the cane. Conservative estimates, based on analysis, have shown that practically 17 tons of such cane are required for one ton of sugar. This is a 50 per cent loss in itself. Rat-infested fields also show a surprising quantity of dead cane lying on the ground after harvesting the live cane. I have some interesting photographs of this. Much of this is cane which has broken off after early rat injury.

Much interesting information has been obtained on the movements and habits of the field rat. It commonly establishes itself in fields as soon as they are well grown with cane and ample shade and cover established. Here they make permanent burrows in the ground and remain until the cane is harvested. Then they move out to adjacent large cane, if present, or to gulches, waste areas, rock piles, etc. There is nothing theoretical in the above statement. I have examined many burrows in fields freshly harvested, in which injury was common, yet I have never found a rat in such burrows.

Poisons of many sorts have been tested on live rats in cages. Several have been found effective, but two stand out at present over all others. Both are well known and recommended in many parts of the world. These are barium carbonate and strychnine. I believe the almost complete disappearance of rats and the almost total cessation of rat injury to cane at Honokaa has been entirely owing to the thorough, systematic, persistent application of these poisons. Cane fields, gulches, and waste areas have been thoroughly poisoned. Much injury occurred before this, but very little following the poisoning. During harvesting, rats are usually seen in fairly large numbers, particularly under piles of cane which have stood along the flumes over night. During the last few months rats were positively rare in such places, where thorough poisoning had been done. Dead rats have been commonly found in poisoned fields, though I have found that the mongoose removes them very quickly after death.

Barium carbonate has been applied in the form of a cake, composed of the poison mixed with wheat flour. During the present year over seven and a half million of these cakes have been made at Honokaa. About 10,368 acres of cane have been treated with this poison. An effort is made to place it about every ten feet in the cane. Several thousand acres of waste area have been similarly treated.

Strychnine has been used on wheat and is highly effective. One ounce of strychnine mixed in starch paste and applied to 25 pounds of grain has been found entirely satisfactory. About 7,000 pounds of strychnine-wheat were applied in cane fields during February and March. Strychnine has been ordered sufficient to manufacture seven tons of poisoned grain at Honokaa for the coming season's work. It is particularly useful for mice, which do not take the barium carbonate cake as readily as the rat.

The cost of the poison work at Honokaa has been very low. The total cost during this year for manufacture and application of both barium carbonate and strychnine-wheat has been about 26 cents per acre. The manufacture and application of the barium carbonate cake has cost about 16 cents per acre.

As indicated above, rats have practically disappeared where poisoning has been thoroughly done, and almost no rat-eaten cane of a fresh nature can be found in such fields. A luna who has just finished the hoeing in four Honokaa fields which have always had an abundance of rat injury in them, reports, after the hoeing, that not a single eaten stick was seen in any of these fields. I have been conducting a series of poison experiments in a small field of Badila cane, always notorious for rat injury. I am over a great deal of this field several times each week. I have not seen more than three sticks freshly eaten into by rats at any time during the many weeks of investigation since it was thoroughly poisoned by barium carbonate cakes. Mice are numerous, however. Poisoned wheat will eliminate them. The mice do no damage to the cane, so far as I have been able to prove, but they are carriers of bubonic plague and their control should be considered an important point in a rodent campaign in Hamakua, where plague is so widespread.

Careful and extensive counts of cane harvested next year should give the final proof of the poison method for rat control. Present examinations in these fields indicate that losses will be very small. We can only assume at present that the elaborate poisoning is responsible for this. Unless proved otherwise, poisoning at Honokaa will no doubt be pursued more vigorously than ever in the future.

Field Experiments

Mr. Verret reports that there are at the present time 121 field experiments on the different plantations. These are distributed by crop year and islands as follows:

Crop Year—	Hawaii	Kauai	Maui	Oahu	Total
1923	17	15	13	14	59
1924	22	28	5	7	62
Total	39	43	18	21	121

These do not include observation tests, of which there are a large number. Deductions are made from these without taking harvesting data. They serve as a means of getting information quickly on various plantation operations. These observation tests may take the form of a well designed experiment or may be inserts here and there where the treatment that has been adopted for a given field is checked against alternate practices which might have been employed. Such tests can often be placed in fields where the areas are not suitable, topographically, for accurate data to be taken, and the adoption of this means of experimenting deserves still wider use than it has received. Nor does the above list include seedling nurseries which are established on practically all plantations. New seedlings are thus observed under different conditions.

The results of the fifty-six field experiments harvested during

the year have been duly reported. It will be recalled that in the last report a review was made of field experiments extending over ten years and deductions were presented. Concerning the work of this year and the general situation with respect to the control of the quality of cane through care in field operations, Mr. Verret makes some important observations:

The results obtained are in line with those of other years, and our general recommendations as given in our last few annual reports are not fundamentally changed.

Before going into a discussion of the results of our 1922 experiments, I desire to call attention to what I believe to be the two most important points in field work at present in regard to the ultimate yields obtained. Expressed a litlte differently, I might say that all improvements effected in these operations give promise of yielding the largest immediate money returns. These two points are: fertilizing at the proper time, and getting the cane to the mill and crushed as soon as possible after burning, or cutting, if the cane is not burned.

During recent years most plantations have been using increased amounts of fertilizer. This has been followed by poorer juices. We do not believe that the poorer juices are due entirely to more fertilizer. Changes in cane varieties, longer harvesting seasons, due to labor shortage, delay in getting burned cane to the mill and unfavovrable climatic conditions all have some effect on the juices. But there is no question that, all other things equal, increasing the nitrogen used, has a tendency to produce poorer juices.

The question arises, how are we to remedy this, or, to put it in another way, how are we to get the most returns from the increased nitrogen used? The answer is, *Fertilize early.* Use large doses and have all fertilizer on at least a year before harvest.

At Waipio, in the last eight years we have increased our fertilization from less than 200 pounds of nitrogen per acre to 310 pounds without lowering the quality of the juices. This was done by fertilizing early in large doses and carefully controlling the water before harvesting.

The tons of cane per ton of sugar at Waipio for four year periods are given as follows:

1915 to 1918 inclusive—8.38 T.C.P.T.S.
1919 to 1922 inclusive—7.89 T.C.P.T.S.

The sugar produced per acre per month has been almost doubled at Waipio in the last eight years. This is due to a number of causes, one of the most important of which is careful fertilizing.

Large returns are obtained from the use of fertilizer, while the larger part of its cost is represented by the cost of the material itself. The labor cost is small. Taken as a whole, there is nothing at which labor can be employed on a plantation which offers such large returns as the applying of fertilizer at the proper time.

The losses caused by delay in getting burned cane to the mill have been discussed before, so it will not be taken up in detail at this time, but the subject is so important that I will mention it again to refresh our minds on the subject.

As a result of over 30 experiments on the different islands, we found that burned cane loses about 3 per cent of its sugar per day after burning. The losses do not amount to 3 per cent a day for the first day or so, but the rate of loss increases as the cane gets older and amounts to 15 per cent in five days.

I believe one factor which is often overlooked is that this sugar loss is caused not only by a deterioration of the juices, but by a loss in cane weights. If cane is burned and left standing, it loses about 1⅓ per cent of its weigiht per day for the first five days; when cut it loses 3 per cent. So even when your juices show no loss, you are about 2 per cent behind in cane weights per day. If we could get all of our cane ground one day sooner after burning than we are now doing, it would mean an increased output of between 15,000 and 20,000 tons of sugar per year for the Islands. Putting it in another way, which may appeal more to some minds, I will take a mill grinding 1,000 tons of cane a day, and assume that the interval between burning and milling is three days. If that is lessened to two days, the saving can be represented by mixed juice flowing continuously out of a one-inch pipe.

The members of the agricultural staff who have coöperated with Mr. Verret in field experiments are: J. H. Midkiff on Kauai, W. W. G. Moir on Maui, H. K. Stender and W. C. Jennings on Hawaii, and F. A. Paris and Y. Kutsunai on Oahu.

Improvement of Sugar Cane Through Bud Selection

The United States Department of Agriculture again granted our request and extended Mr. A. D. Shamel a leave of absence to visit these islands and continue the work of improving our standard varieties of sugar cane by bud selection. This work was started by him on his first visit to the islands in March, 1920.

The work this year was characterized by the coöperation of a large number of plantations, and an attempt has been made to meet the requests of all the plantations that wished to participate. The outlook for success in a commercial way becomes more promising as the project advances. Mr. Shamel has prepared an article, which will be issued for circulation among the plantations, in which he brings together much of our present information on the subject. The paper was written for the special purpose of aiding those who are entering into cane improvement on the plantations. Nearly all the members of the agricultural department have taken part in this work: W. W. G. Moir, F. A. Paris, W. C. Jennings, H. K. Stender, Y. Kutsunai, J. H. Midkiff, G. B. Grant; and the subject has also received much personal attention from Mr. Verret. Mr. Caum has cooperated with Mr. Moir in the work on Maui.

Selection work has been undertaken with the following varie-

ties: H 109, Yellow Caledonia, D 1135, Yellow Tip, Striped Tip, and Striped Mexican.

A number of the plantations have appointed men to give this subject special consideration. All of these men are cooperating with the Experiment Station. Among them are: W. P. Alexander, John Robertson, C. S. Jamison, J. C. Thompson, G. B. Grant, D. H. Hitchcock, E. E. Naquin, Donald Seaton, S. Milne, H. E. Starratt, C. F. Poole, Neil Webster, F. A. E. Abel.

Aside from these representatives, many of the plantation managers have themselves taken an active personal interest in this subject.

It will therefore be seen that the project of the improvement of cane is provided with a personnel of workers which is steadily growing in number, and this, together with the great interest being shown by all, should assure us of success in the undertaking to provide our fields with better strains of cane.

The investigation has advanced to a point where within the next few years we should be able to determine, under practical field conditions, the form and degree of benefit which may be reasonably expected.

In selecting the superior individual plants, Mr. Verret attaches great importance to the study of types or strains in the different varieties. He says:

> We believe that when the different types are isolated and fixed (if they stay fixed) and the best ones identified, that the work will be greatly simplified. Stool selection is only a step in the work of locating the types we are after.
>
> When the types are once found, they can be spread rapidly by spaced planting of all good seed, regardless of stool. Of course, along with this, small pedigreed fields, consisting of the best stools of these good types will be carried along to prevent deterioration and for possible improvement, in the same way that the best animals are used in building up herds.
>
> Our selected progenies of Caledonia and H 109 indicate very strongly that several types of each of these canes exist. Both Mr. Moir and Mr. Paris have isolated types of H 109 which seem very distinct and are rapid growers. These are being studied and spread to larger areas.

In reporting upon experiments which they started on Maui following Mr. Shamel's first visit in 1920, Mr. Moir and Mr. Caum also spoke of the promise that attaches to learning to recognize and isolate types.

The work with cane is therefore following close upon the developments in citrus. The bulletins of the United States Department of Agriculture by A. D. Shamel and his co-workers show how the standard varieties of oranges, grape-fruit, and

lemons have been divided into distinct strains, which can be distinguished at a glance by a trained observer. These types, once separated from the conglomeration of strains that are called a variety, are then dealt with in a practical way on much the same basis as varieties themselves.

Seedling Canes

During the past year a number of seedlings from the propagations of previous years on Oahu, Kauai, Maui, and Hawaii have come into prominence. From the showing made by these canes, it is almost certain that our list of good commercial varieties will be materially increased.

During the coming tasseling season, Mr. Verret plans to grow a large number of seedlings. The work will be done mainly on Oahu and on Hawaii. The work on Oahu will be done in Honolulu, while the work on Hawaii will be done in Hamakua and Kohala. Mr. Verret gives the following account of the seedling work:

On Hawaii we plan to get all the seedlings we can of Tip parentage, more especially crosses of the Tips witih D 1135. We also hope to get Badila and Uba with tips if we can get tassels from these varieties at the same time. We shall plant all the tassels we can handle of D 1135 and tips when these varieties are growing next to each other. In this way we shall get the desired crosses.

On Kauai we have large numbers of seedlings now, so we plan to concentrate on the selection of these rather than in growing new ones. In our work this year we found several hundred giving as good or better yields than H 109. These are being spread out as rapidly as possible for further trial. Work of this kind is necessarily slow. A crop must be grown two years, and several ratoons must be had before the value of a seedling can be determined.

At Hilo Sugar Company, 264 seedlings of 1920 propagation were selected last year from a total of 2,208. At the present time a number of these are showing as well or better than the Caledonia checks. At Honomu, 98 growing in a third test are showing up well. A number of 1917 propagation seedlings were harvested at Hilo Sugar Company. None were as good as the Caledonia. The test is being continued with the three best ones. The rest are to be plowed up.

At Honokaa several seedlings show distinct promise. O. P. 1917 number 229, and 431 especially. They both seem very good ratooners.

A number of the Maui seedlings are coming ahead rapidly and seem as good as H 109. Several are now planted to areas of half an acre or more.

Wailuku Nos. 1 to 8 are probably the best ones. These are the old numbers 22023, 32310, 31626, 70, 75, 22606, 51601, and 130507, respectively.

A number of the O. P. 1918 seedlings are being spread. The best ones of these given H numbers are: H89102, H8994, H8949 and H8961. These correspond to the old numbers 102, 94, 49 and 64.

Native Canes

The collection of native sugar canes which was assembled by Mr. Caum and Mr. Moir, is being grown for study and as a source of material to be used in seedling propagation. A number of the seedlings grown this year are from the canes of this collection as parents. "Among these native canes," thinks Dr. Lyon, "are several varieties possessing constitutional characters which we should attempt to incorporate in new varieties by employing the native canes as parents in our cane breeding work."

Cane Varieties

Concerning cane varieties, Mr. Verret makes the following comment:

In a number of tests in the more unfavorable districts this year, the Tip canes have shown up very favorably. This is especially true at the higher elevations, from 1300 to 1500 feet and up. The Tip canes are strong growers. Being good ratooners, they are cheaper to raise than most of our other canes in the upper fields.

Unfortunately, the Tip canes are rather freely susceptible to Mosaic disease, but not more so than D 117. We feel confident that the Tip canes could be substituted for D 117 with distinct advantage.

In planting the Tip canes (we belieive Yellow Tip is better than Striped Tip in most places) proper precautions should be taken against the spread of Mosaic.

The Department of Botany has been devoting a great deal of time to the study of Mosaic disease and as a result we now know a great deal more about it than we did. Some of the measures which they recommend for the control of mosaic are as follows: "the planting of disease free seed;" the "rogueing out" of diseased plants; as clean cultivation as possible in order to keep down grasses that carry the disease or harbor the corn aphid; the eradication of corn or other aphid breeding plants from the vicinity of cane fields.

With the above precautions we believe that Yellow Tip could be slowly extended in our upper plantings.

In the meantime we are endeavoring to get Tip seedlings with the good qualities of the parent and more resistance to Mosaic.

Cultivation

If each operation in connection with sugar production could be tested experimentally to determine its bearing upon the yield, the field operations could be planned accordingly. On the subject of cultivation Mr. Verret says:

Our experiments in off-barring and hilling continue to show no increase in cane yields. It seems to us that for most island soils the ideal to work to is to plow as deep as is advisable (when the soil is thin it may be well to subsoil), prepare well and make a good job of planting. After that, control weeds the cheapest way, with the least disturbance to the cane roots possible.

Applying Fertilizer

Much of the benefit that can be accomplished with fertilizers will not be realized if these materials are not applied at the proper time. It is risky to delay the second season fertilization too long. Too many small doses are not so good for the cane as a few big ones. Concerning this Mr. Verret reports:

The best returns are obtained from applying all fertilizer in from two to three doses. The earlier it is done the second year, the better. I am becoming firmly convinced that it would pay to stop harvesting if necessary, for a short time, to get second season fertilization done in time.

Readily Soluble Nitrogen

Experiments show that there is a distinct advantage in employing the readily soluble forms of nitrogen rather than those to be derived at greater expense, such as tankage, dried blood, and other forms of organic materials. Concerning this matter Mr. Verret reports:

We obtain our best returns from nitrogen in its most soluble form. That is nitrogen from nitrate of soda, amonium sulfate and ammonium nitrate, produce more cane per unit than nitrogen from organic sources. There seems to be little difference with nitrogen from nitrate of soda, ammonium sulfate or ammonium nitrate. Java reports the same thing.

The preference between the several soluble nitrogen salts would depend, it appears, largely on the question of price per unit of nitrogen. This fact is fully appreciated by the local fertilizer interests, who follow the market for any price advantages that can be obtained on purchases for the plantations.

How Much Nitrogen to Apply

The actual amount of nitrogen to be applied is a matter which must be determined by each plantation for each field or group of fields. A summary of our deductions from many field experiments on this subject is furnished by Mr. Verret:

Our experiments show the proper amount of nitrogen to use usually varies from 150 to over 250 pounds per acre, according to conditions. Under the best conditions of soil, moisture, heat, freedom from disease or insect pests, and a good stand of cane, from 250 to 300 pounds of nitrogen is profitable. As conditons become poorer and introduce other limiting factors, the amount of nitirogen which can be used to advantage becomes less. It is not possible to state the amount of fertilizer to use and make it of general application. The nearest approach we can make to a standard practice is to suggest applying 200 pounds of nitirogen per acre for good normal conditions in good

fields, and then raising or lowering this amount as conditions change. Under present conditions the majoritiy of fields will take less rather than more than 200 pounds.

Phosphoric Acid

Experiments this year showed returns from phosphates on the upper lands of plantations on Oahu and Kauai, and on Hawaii in the Hamakua and Kau districts.

Potash

Experiments continue to show that applications of potash give splendid returns in the Hilo district. One test was reported in Hamakua which gave positive results, but all other tests gave negative results.

Liming

The results reported during the last year on the subject of liming are in keeping with those which we formerly reported. Where any gains in yield at all are found from lime or coral sand treatments, they are not great enough to be economically profitable. Extensive operations in liming the cane lands of this Territory may, we think, be withheld unless there is evidence from experiments that lime is required.

The Waipio Yields

The investigation at Waipio pertaining to the profitable limit of intensive agriculture is proving very interesting.

The production of 13 to 14 tons of sugar to the acre has become a routine procedure. The yield of 15.87 tons of sugar, secured in plant cane in 1920, was not repeated in the ratoons. The first ratoons, 1922 crop, gave 14.88 tons of sugar per acre.

If, however, we compare the ratoons and plant cane on the basis of both area and time, it is found that the yields are essentially the same, or slightly better in the ratoons, 0.622 tons of sugar per acre-month, against 0.650 in the ratoons.

It is important to find how well the variety H 109 holds up as second and third ratoons under heavy cropping. To illustrate this, we can take the case of a small field which was harvested as plant cane in 1918, and has since then been harvested as ratoons in 1919, 1921, and again in 1922.

The yield has advanced steadily at each harvest, when calculated on the acre-month (per acre per month) basis:

1918	crop	Plant.....	(15½	months)	.383	ton	sugar	per	acre-month	
1919	"	1st Ratoons...	(11½	")	.513	"	"	"	"	"
1921	"	2nd Ratoons...	(21½	")	.575	"	"	"	"	"
1922	"	3rd Ratoons...	(15	")	.630	"	"	"	"	"

In order that the significance of these yields may be better understood, they are shown below with their acre-year and 2 acre-year equivalents:

Acre-Month Yield	Acre-Year Equivalent	2-Acre Year Equivalent
.383 ton sugar	4.596 tons sugar	9.192 tons sugar
.513 " "	6.156 " "	12.312 " "
.575 " "	6.900 " "	13.800 " "
.630 " "	7.560 " "	15.120 " "

It is clear from the table, we think, that sugar production at the rate of .63 ton per acre-month is the same as 15.12 tons of sugar per acre for a cropping period of two years.

We have been interested in seeing that two plantations, the Ewa Plantation Company and the Waianae Company, have adopted the plan of measuring yields on the acre-month basis. We feel that the development of our field methods to their present stage at Waipio would not have been feasible without this standard of comparison.

By the aid of this system of gauging yields both on an area and a time basis, we are working away from a 24-month cropping period in favor of a 15- to 20-month crop, or, say, a 14- to 16-month crop alternating with a 17- to 21-month crop.

We believe that through work now under way, there is reasonable promise of higher production per acre-month than has been obtained thus far. The high yields obtained to date have not been produced at a higher cost *per ton* in water or in man-days, but rather at a distinct economy on these two important scores.

The yields of over 15 tons of sugar per acre on several fields at the Ewa Plantation Company during the 1922 crop have shown that where the climate is right a high yield of sugar is also practicable under the conditions under which a large plantation operates.

In the appendix of this report, a table prepared by Mr. Verret shows the 1922 yields at Waipio in some detail. In his work at the Substation, Mr. Verret has had the assistance of F. A. Paris, who has contributed a great deal to the improvement of our field practices.

Concerning the work of the Waipio Substation Mr. Verret says:

We believe we are safe in saying that from now on our crops at Waipio should average over 800 tons of sugar per year from our 130 acres in cultivation.

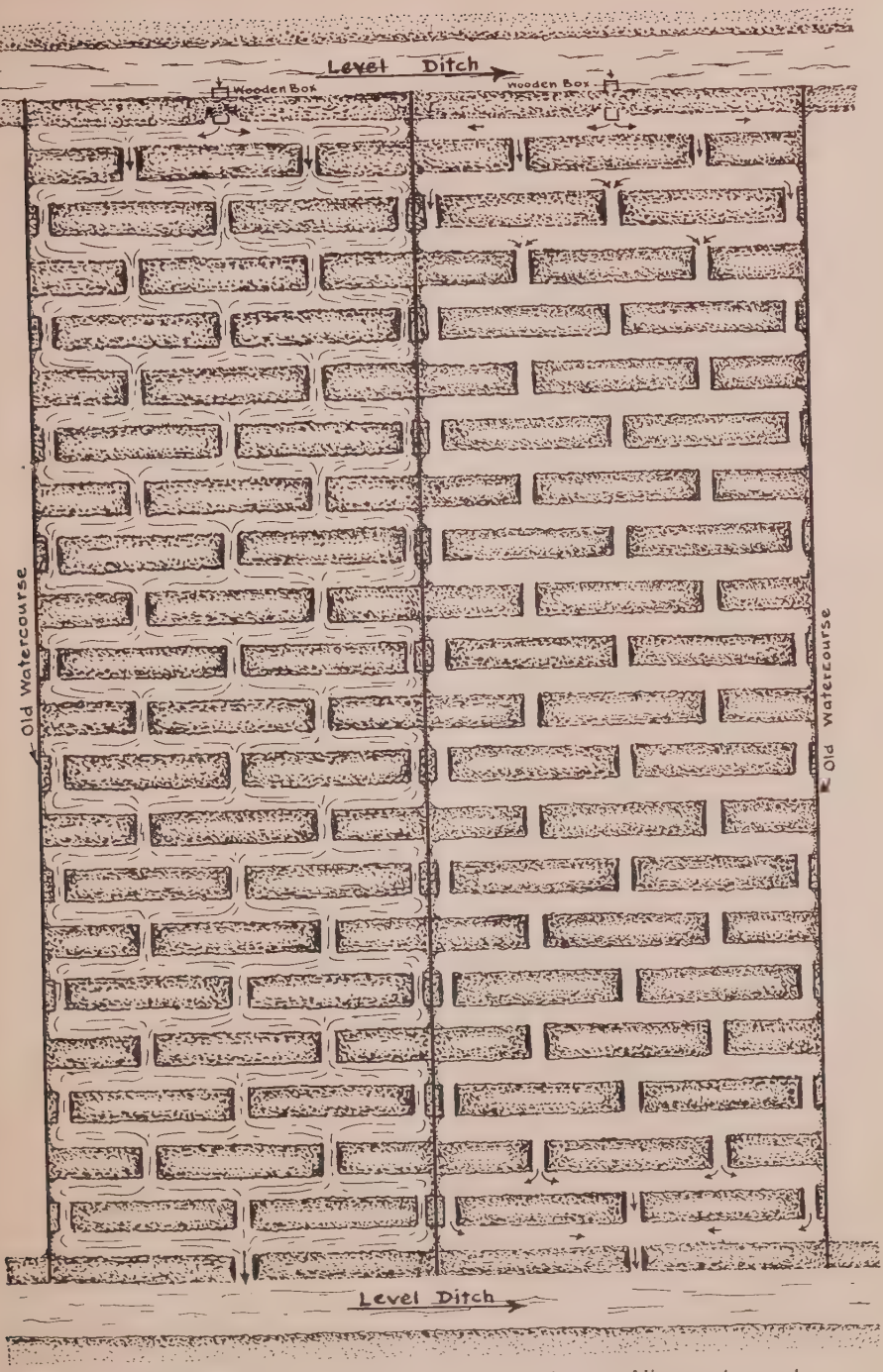
We have a total of 18¼ acres planted to selected progenies, practically all of which is H 109. Although the majority of these progenies do not now appear to be superior to average run H 109, a few do seem to stand out above the rest. We plan to plant next year five

to ten acres from half a dozen or so of these more promising strains.

We are concentrating our efforts, as much as possible, at Waipio, to the isolation and study of superior strains of cane which will reproduce themselves true to type. When these strains are once isolated, with sufficient study it may become possible to recognize them in the field. When this is done the problem of bud selection will be solved. We regard this study of types or strains as the most important phase of bud selection work.

Waipio System of Irrigation

In connection with the many modifications of the standard practice of irrigation, we wish to present one which has been installed at Waipio and which is proving more satisfactory than the old system from the standpoint of economy of labor and facility of distributing the water. The system is due to Mr. Paris and is described by Mr. Verret as follows:



Waipio system of irrigation, based on the Larsen-Allen systems at Kilauea. Plan shows method of changing from the old to the new system of irrigation. Arrows indicate flow of water. Cane can be either in furrow or on ridge. For sake of simplicity the ditches and lines are here laid straight. This of course is not necessary; it is only necessary that the lines be level.

It is intended for use on palis and places where the grade is fair. It is not intended for level places. One of the advantages of the system is that no changes are made in methods of planting. All that is necessary is to be very careful that all lines are level. In plant cane, it may be best not to introduce the system until the ground is fairly well packed, otherwise there may be some washing and cutting and the water will not distribute itself evenly.

Reference to the diagram attached will show the working of the system. As laid out at Waipio each watercourse is used as a unit in the system. The water is introduced into the lines by means of a box, 4″x6″ inside measurement. The box is placed in the center of the watercourse. (See diagram.)

Depending on the capacitiy of the "level ditch" and the grade, a number of these boxes are put on the same level, in the same way as the small pipes in the Kilauea system. The next series of boxes start on a lower level and so on. Between each series an over-flow gate is placed. In this way a number of watercourses can be irrigated at one time by one man.

The first line is then cut in two places. In a 30-foot line, for instance, the cuts will be 7½′ from the old water course, leaving an uncut section in the middle 15 feet long. The second line is cut in three places; one in the middle and one at each end. The third line is again cut as the first was, the fourth like the second. These alternate cuttings are then continued to the next level ditch.

The cuts should be about 18 inches wide, and about 3 inches from the bottom of the furrow. Care should be exercised to have the bottom of all cuts in one line at the same level, otherwise more water will flow down the lower one and cause uneven distribution. Unless the soil is compact and does not wash, it is advisable to protect the bottom of the cuts with trash, or, better still, with some mulching paper.

As the water flows down, its velocity is checked in the level line, and it therefore never flows very fast and washing is at a minimum, but it is nevertheless better to protect the bottom of cuts. That saves trouble when the cane is big. From our limited experience, we believe that on steep palis this system will give less trouble than the old one, where watercourses rapidly wash out into deep ditches.

Manoa Substation

The Manoa Substation is proving of value in our work to obtain sugar cane vareities which can withstand the more adverse conditions of the rainy districts. Our rainfall in upper Manoa compares very closely with that of the Hilo district, and the wind velocity is equal to that of Hamakua or Kohala. Any seedlings which thrive there are promising material to send out to the plantations of Hawaii and windward Kauai.

The following account of the substation work is due to Mr. Verret:

We now have about twelve acres in cane at Manoa Substation. The larger part of this is planted to new seedlings, where we hope to de-

velop new canes suited to rainy districts. In some respects Manoa is peculiarly well suited to seedling work. The conditions there are rather hard and all poor seedlings are rapidly eliminated by natural causes, thus simplifying and speeding up the work.

Although we have worked but a few years in Manoa, we already have sixteen new seedlings which are considered good enough to try out on the plantations. They have accordingly been sent out to a number of places for further trials. In addition to the above we have another twenty or so which are coming along very well and some of which we hope to begin sending out to the plantations within a year or so. We have a total of 4600 seedlings now planted in Manoa.

The Manoa plots are also very useful as a source of seed cane. There is a more or less continuous demand on the Station for seed of the various standard canes and of the better known seedlings. For this purpose we have plots at Manoa planted to these various canes. This is a better arrangement than to have to grow these canes at Makiki, where the land is much more valuable for other purposes.

We feel assured that with a few years more work at Manoa we shall develop a cane of a value corresponding to that of Caledonia.

Mr. Kutsunai lives at the Manoa Substation and is in charge of the work there.

Factory Inspections

Mr. McAllep and Mr. McCleery have this year met all the requests for factory inspections, numbering thirty-two.

The following inspections were made by Mr. McAllep:

Ewa Plantation Company,
Olowalu Company (2),
Pioneer Mill Company, Ltd.,
Kipahulu Sugar Company,
Kaeleku Sugar Company, Ltd.
Maui Agricultural Company,
Honokaa Sugar Company,
Hamakua Mill Company,
Kaiwiki Sugar Company, Ltd.
Laupahoehoe Sugar Company,
Waiakea Mill Company,
Hutchinson Sugar Plantation Company,
Hawaiian Agricultural Company,
Olaa Sugar Company, Ltd.

The following inspections were made by Mr. McCleery:

Waimanalo Sugar Company (2),
Waianae Company,
Kekaha Sugar Company, Ltd.
Hawaiian Sugar Company,
McBryde Sugar Company, Ltd.
Koloa Sugar Company,
Lihue Plantation Company, Ltd.
Makee Sugar Company,

Kilauea Sugar Plantation Company,
Hawi Mill & Plantation Company, Ltd.
Halawa Plantation, Ltd.
Union Mill Company,
Niulii Mill & Plantation,
Kohala Sugar Company,
Oahu Sugar Company, Ltd.
Waialua Agricultural Company, Ltd.

According to Mr. McAllep, the features noted during these visits were "steadier operation than last year, made possible by a better supply of cane; a tendency in many quarters to pay less attention to the extraction; increased interest in clarification; less attention in many cases to maintaining the grain of the commercial sugar above the standard, and a tendency to reduce the amount of low grade massecuite in storage."

Clarification Investigations

The subject of clarification has been investigated by Mr. McAllep and Mr. Bomonti to the end that there is now definite information that facility in clarification is associated with adequate phosphoric acid content of the juices. It has further been shown that by handling the juices of most mills at a little higher alkalinity than formerly, better results have been obtained. An account of this work is given by Mr. McAllep:

The greater part of Mr. Bomonti's time has been taken up with a continuation of the clarification investigation. Since the publication of the last article on this subject in the Record, a study has been made of time and temperature conditions, reaction to phenolphthalein and litmus, and hydrogen ion concentration with reference to the inversion of sucrose and also the destruction of glucose during clarification. Data secured have not yet been analyzed and put in shape for publication. They indicate, however, that there is a somewhat narrow region more alkaline than the neutral point to litmus and more acid than the neutral point to phenolphthalein, where, in a reasonable length of time, at temperatures up to slightly below the boiling point, sucrose is not inverted and glucose is not destroyed. According to present information, when the juice previous to heating is limed to phenolphthalein neutrality, the resulting reaction is within this neutral region, but at a slightly more alkaline reaction lime begins to attack the glucose.

Optical sucrose methods were checked against chemical sucrose determinations in connection with the above work to determine whether or not the optical methods give comparable results before and after clarification, particularly after a strongly alkaline clarification. It was found that the Walker inversion method does give comparable results.

The ground covered by the clarification investigation has been extended by making laboratory clarification experiments during fac-

tory inspections. Such experiments have been made at most of the factories inspected. The results have been in close agreement with previous work at this Station. With but two or three exceptions, the largest increases in purity and the clearest settled juice have been obtained with a more alkaline clarification than has been the usual Hawaiian practice. Our opinion that lining the cold juice to the neutral point to phenolphthalein is the most practicable method for controlling the clarification to secure the clearest settled juices and the maximum purification has been confirmed, for in nearly all cases the maximum increase in purity accompanied by rapid settling has been obtained either at the reaction reached in this way or between this reaction and neutrality to phenolphthalein in the clarified juice.

Phosphoric acid has also been determined in most of the juices available during factory inspections, using a simple and rapid, yet sufficiently accurate method development by Mr. Bomonti of this Station. The amount found has varied from .005 to .14 per cent. Such wide variations suggests the probability that these determinations, undertaken because of their bearing on manufacturing operations will prove of value in controlling agricultural practice. Our opinion that the amount of phosphoric acid in a juice is a very important factor in the size of the increase in purity and the turbidity of the settled juice has been fully confirmed. Out tentative estimate that .03 to .035 per cent of phosphoric acid was necessary for a satisfactory clarification, based on laboratory work with Oahu juices is, however, subject to some modification. Some juices as low as .015 to .02 per cent have been found that settled fairly satisfactorily under factory conditions when clarified with the proper amount of lime. The settled juices, however, were far from clear. Turbidity diminishes as the phosphoric acid content increases, and at .03 to .04 percent disappears. When the phosphoric acid content is above the latter amount, brilliantly clear juices can be secured.

This season trials have been made in many factories of conducting the clarification at a more alkaline reaction than has been the common Hawaiian practice. In the greater number of cases, the settled juices have been clearer, the increases in purity larger, the undetermined losses smaller, and the reslts have been considered satisfactory, though sometimes the pratice could not be continued because of the extra duty imposed on the filter presses. In a few places the results have not been satisfactory and difficulties have been encountered, due to slow settling, difficult press work, increased amount of scale on heating surfaces, slow boiling and difficult working low grade products.

The writer would make a following comment with reference to these difficulties. As the alkalinity at which the clarification is carried is increased the volume of the settlings increases. An increased amount of lime will then increase the work of the filter presses for they will have a larger volume of liquid and also a slightly greater amount of solids to handle. While the subject of settling has not yet been investigated thoroughly, the writer has so far failed to observe anything either in laboratory work or factory practice indicating slower settling in the more alkaline juices. Settling is usually rapid till the settlings reach a certain volume which varies with the composition of the juice and the alkalinity. Further settling then becomes

extremely slow. Frequently, when sufficient lime is used to secure the maximum purification, this volume, to which the mud will settle in a reasonable time, is greater than the capacity of the settling tank below the lower draw-off cock. It is probable that this failure of the mud to settle to the expected volume is often attributed to slow settling rather than to the fact that the settlings in the more alkaline juices normally occupy a larger volume. The other difficulties noted above are the results of over-liming. This may have been due to over-liming a part of the juices, for instance, those having a small lime requirement or to adding lime at the filter presses after the full lime requirement has already been used in clarification. It is also possible that some juices may be found that give trouble when limed to the point indicated as desirable by the experimental work.

The Commercial Value of Last Mill Juice

In a discussion bearing upon the profitable limit of high extraction, we have heard the question as to whether the value of the last mill juice could be judged on the basis of its analysis. Some contended that the impurities in these low grade juices might be of such a nature as to materially handicap crystallization. In investigations arranged by Mr. McAllep, this point seems to have been cleared. He states:

During November of last year, through the courtesy of the Kahuku Plantation Company, this was investigated on a semi-manufacturing scale. Conditions under which the experiment was conducted were: poor quality cane, very low purity juices, light maceration and comparatively low extraction. The molasses, resulting from the use of apparatus about the equivalent of that used in factory practice, was slightly under 34 gravity purity, indicating a yield of 67 per cent of the sucrose from last mill juice of slightly under 50 apparent purity. Reboiling this molasses in experimental apparatus at this Station reduced the purity to 27.77. This approximates the point reached with other Hawaiian molasses and indicates that so far as crystallization is concerned, the molasses resulting from this experiment was not abnormal. Details will be found in the Record, Vol. 26, page 196.

This experiment definitely disproves the theory that sugar cannot be made from last mill juice. Opinions have also been expressed that the last mill juice is less valuable than its purity indicates. Though this opinion may have some foundation on theoretical grounds, the juices used in this experiment proved to be much more valuable than would be inferred from their analysis.

In August of this year a repetition of this experiment was started at Oahu Sugar Company, with juices from cane of good quality, heavy maceration and 97 extraction. Last mill juice of 69.6 apparent purity was clarified, evaporated and boiled to a massecuite of 72.75 purity. The clarification was very unsatisfactory because of the low concentration and very low phosphoric acid content of the juice. Though the syrup contained a large amount of suspended matter, no difficulty was experienced in boiling it to a massecuite of excellent grain,

which dried well in a laboratory centrifugal. The resulting sugar was 84.5 polarization and the molasses 45 gravity purity. As the quantity of molasses was not sufficient to continue with a second boiling on a semi-manufacturing scale, the crystallization of sugar from this molasses is being studied in the experimental apparatus at this Station.

When the work on this project, now under way and planned, is completed, we can give a definite answer, based on actual investigation, to the question, what is the value of the last mill juice? So far we have found no indication that it is less valuable than its analysis indicates.

Refining Properties of Commercial Sugar

While on vacation in California, Mr. McAllep visited the refinery of the California and Hawaiian Sugar Refining Corporation, and that of the Western Refinery. The following information, bearing upon the refining qualities of Hawaiian raw sugars, is reported by him:

Commercial Sugar

No special investigation of the refining qualities of sugar has been made this year. All such work both at this Station and at Crockett was discontinued at the beginning of the 1922 season. The writer, however, visited both Crockett and the Western Refinery during a recent trip to the mainland to obtain information as to what effect increasing the polarization of Hawaiian sugars had had on refining operations. At both refineries every facility for obtaining the desired information was offered and the writer wishes to express his appreciation of the courtesies shown him.

In 1920 the technical committee of the Sugar Factors Company and the staff at Crockett calculated that the refinery should recover 1.6% more sugar per degree increase in polarization above 96. As compensation in this amount gives better returns to the plantations per unit of sugar in the mixed juice, these calculations indicated that the manufacture of higher polarizing raws would result in a more economical over-all process. On these and other considerations compensation for higher polarizations up to 97.5 was placed on the above basis when a revised contract was drawn up. At the time the average polarization at Crockett approximated 96.6. It was thought desirable to limit the increase in polarization to about a half of one degree to see whether the results obtained in the refinery would confirm the calculations. For this reason no extra compensation was paid for polarizations above 97.5. The polarization of the raw sugar now received at Crockett averages between 97.1 and 97.2, an increase of from 5 to 6 tenths of a degree. At the Western Refinery the increase has been smaller, amounting to between 2 and 3 tenths. Comparisons at Crockett are between the 1920 and the 1922 seasons, the low capacity at which the refinery was operated during 1921 detracting from the value of comparison with that year.

Recovery

The calculated increase in recovery has been realized at Crockett and there has been a saving in expense because of the smaller quan-

tity of non sugar handled. At the Western the statement was also made that the expected recovery had been realized, but the writer is not certain whether this statement referred to 1.6% or the slightly different figures used in the Western contract. As the increase in polarization has resulted in a profit both to the plantations and to Crockett, the change has resulted in a more economical over-all process. The calculations previously referred to indicate that still higher polarizations are desirable and as no unfavourable features that can be attributed to the change in polarization have appeared, it would now seem in order to consider a further increase of, say, to 97.5. This view is supported by the opinion of the technical men at the Western Refinery which is that 97.5 is the most desirable polarization from a refinery operating standpoint. If the point up to which payment is made for increased polarization is changed from 97.5 to 98.0, the sugar received at Crockett will probably approximate 97.5 polarization.

The possibility that deterioration might be encountered at higher polarizations is the only objection to the suggested change that has occurred to the writer. While this problem has been solved for sugars of ordinary polarizations, our experience with high polarizations is rather limited. According to statements made at Crocket, however, no increase in the amount of fermented or sweated sugar has accompanied the increase in polarization from 96.5 to 97, and it is improbable that a further increase of half a degree will cause any difficulty if the sugar is dried to an appropriate moisture content.

Grain

As grain separations have been discontinued at Crockett and the commercial sugar control was discontinued at this Station at the beginning of the 1922 season, no definite figures for this characteristic are available. The quality of the grain, however, both with respect to size and conglomerates, is the principal factor influencing the amount of water required for the preliminary washing of the sugar at the refinery. At Crockett the raw sugar is washed to a standard purity of 99.0. Though the amount of water required should have been less after the increase in polarization, actually an increased amount has been required, indicating a much poorer grain than in 1920. In this connection the writer would note that grain separations and observations made in the course of factory inspection work had previously convinced him that the average quality of the grain was much poorer than in 1920.

Keeping the grain up to the standard, providing the factories are adequately equipped, involves careful and intelligent handling of the pans rather than any considerable extra expense. As it is also probable that any necessary expense in keeping the grain up to the standard is fully off-set by increased recoveries realized as the result of more care and attention given the boiling process, it is questionable whether allowing the quality of the grain to deteriorate has resulted in any savings at the plantations. The increased amount of water necessary at the refinery affination station amounts to 8 or 10 pounds per ton of raw sugar; an increase of some 12%. The evaporation of this extra water entails a considerable extra expense at the refinery. As individual plantations are now directly affected by anything that

increases the refining cost it would seem desirable to bring the grain back to at least the 1920 quality.

Lumps of hardened massecuite and also caked sugar affect the amount of water required for washing, but it is improbable that these are important factors in the increased requirement noted above.

A year ago the writer considered that the commercial sugar control carried on at this Station for several seasons was no longer necessary, as the plantations should have sufficient information to maintain the quality of the grain, particularly as grain separations were available on request. Discontinuing the control, however, has created the impression in many quarters that it is no longer particularly essential to keep the grain up to the standard. The writer now considers it desirable to make a sufficient number of grain separations either at Crockett or this Station so that definite figures for the quality of the grain may be available. An investigation of the cause of conglomerate grain is also desirable.

Filtration

Positive statements were made at both refineries that no improvement in filtration had been brought about by the increase in polarization. At Crockett the filtration of sugar from nine factories was classified as good, fair and poor. At the Western Refinery the melt house foreman had considerably more information and was able to so classify sugar from about two-thirds of the factories. The most difficult filtration is in the early part of the season. Towards the middle of the season there is a considerable improvement, while towards the end the filtration again becomes difficult. After the melted raw sugar has once been filtered it can be refiltered almost as readily as a solution of refined sugar of the same density.

Mr. Blowski of the Crockett staff some years ago made a test that appears to have a direct bearing on this question. The insoluble matter consisting mostly of fiber was separated from a quantity of raw sugar. One portion of this fiber was treated with lime and phosphoric acid in the proportion then used in refinery practice, while another portion was heated with water alone. The latter portion filtered six times faster than that treated with lime and phosphoric acid.

Up to the present time our information on this subject has been but little more than that the filtration of Hawaiian sugar is difficult. In the absence of a practicable filtration method we have been unable to make any investigation, and information from the refinery has been very meager. The above information, however, throws considerable light on the subject. The fact that the increase in polarization did not cause an improvement in filtration, more or less in proportion to the reduced quantity of non sugar, and that when filtered a second time the raw sugar syrups filter practically as easily as a white sugar liquor is a definite indication that the difficulty is due to insoluble or colloidal matter, rather than to viscosity caused by the nature of the soluble non sugar. This gives us some idea of the direction in which it is necessary to proceed to remedy the difficulty.

With respect to the classification of the sugars according to their filtration characteristics, such study as the writer has so far been able to give these lists has failed to correlate filtration characteristics with variety of cane, high or low extraction, high or low recovery or details

of factory practice. No doubt further study will throw at least some light on the subject.

Should further work confirm the results of Mr. Blowski's experiment, we have a definite indication that filtration will be improved by removing suspended matter from the juice as thoroughly as possible before clarification. If this is the case the apparatus for passing mill juices through a 100 mesh screen, invented by Mr. S. S. Peck, which the writer understands is now in successful operation at Kahuku Plantation, should improve the filtration of the sugar. It should be noted that the effect on filtration found by Mr. Blowski is in addition to the depression of the purity reported by Mr. Bomonti and the writer in a recent article on the effect of cush cush during clarification, for in the latter work the material that caused the effect on filtration noted by Mr. Blowski had been removed from the solution. Mr. Peck's apparatus will permit a purer syrup to be secured from a given mixed juice. If it also improves the filtering quality of the sugar it should prove one of the most valuable improvements available for Hawaiian factories in recent years.

Other Refining Characteristics

The problem of caked sugar seems to be fairly well solved. Very little caked sugar is now received at Crockett, except that which has become hard as a result of being stored close to the boilers during shipment.

The problem of dark seed grain also seems to be practically solved. It is no longer regarded as troublesome at either refinery.

The ash content has decreased more or less in proportion to the increase in polarization. Exact figures for this, however, are not available at the present time. At Crockett it is considered that difficulties due to scale on heating surfaces had not been lessened. At the Western Refinery the ash content is considered one of the most important factors affecting the refining qualities of the sugar, a high ash content giving them trouble throughout the process.

The Value of the Upper Joints of the Cane

Progress was made by Mr. McCleery in assisting the agricultural department to determine the correct point at which cane should be topped in harvesting. The results indicate that juices capable of yielding sugar can be obtained from less mature joints than might be supposed. The question of deterioration of these immature joints has a bearing on the situation, however, and this is brought out by Mr. McAllep, who says:

All work so far has been on cane one day after harvesting. The question of deterioration, however, must also be studied, for presumably these immature joints deteriorate faster than the rest of the cane. The determination of the most desirable point to top the cane also involves a balancing of the cost of harvesting the extra material and the increased cost of manufacturing sugar from low purity juices against the value of the recoverable sugar. Further investigation was postponed when it became necessary to take up other work.

A Soil Survey of Plantation Fields

Mr. Stewart has cooperated with several plantations in arriving at a better understanding of their soils and the problems they present. These soil surveys are usually designed with special reference to the conditions encountered. They are handled in a cooperative way with reference to the work of the agricultural department in placing or interpreting the results of field experiments. The fertilizer requirements of a soil cannot be determined by soil analysis without recourse to field experiments. Field experiments cannot be properly located and interpreted without the aid of laboratory work. During the year the soils of Ewa Plantation Company, Kaeleku Sugar Company, Waimanalo Sugar Company, Pioneer Mill Company and Koloa Sugar Company have received special attention. An account of these soil investigations is given in a report by Mr. Stewart, which reads substantially, as follows:

Ewa Plantation Company

Our results showed that the soils were well supplied, as a whole, with the major plant foods. A possible slight deficiency in available phosphates was indicated in some samples, and a few others contained a minimum content of potash.

The policy of field experimentation at Ewa, under Mr. W. P. Alexander, is intended to develop all possible correlations between the data obtained on the soil composition and actual fertilizer response. A properly planned series of observation tests and field trials should enable a plantation to get the greatest possible value from the money spent on fertilization. If potash and phosphate tests are installed in fields that are high in these nutrients, it should be perfectly safe to withhold the special plant food in question from the balance of the field. Any striking decrease in crop, due to the absence of complete fertilizer, will be readily detected. If the difference is very great it will be clearly visible to the eye and a complete fertilizer can be applied to the growing crop. I believe this careful study of the needs of the various fields will prove profitable on any of the larger plantations. Such work promises to prove very valuable to us here at the Station in developing our knowledge of the requirements of the island soils.

We also determined the soil reaction and soluble salts present in the samples from the Ewa fields. In order to have some standard of comparisons, as to the original condition of this land, we collected a series of samples from the borders of fields and banks, where irrigating water and fertilizer salts had probably not percolated. Part of the samples appeared to be free from contamination. A comparison of these border samples with the samples from the fields showed that there is no great accumulation of salts from the irrigating water and very little increase in alkalinity due to the continued use of nitrate of soda. I feel that these results are very important for the island agriculture and shall discuss them more fully under our experiments upon the effect of fertilizing salts.

Kaeleku Sugar Company

All the soils are well supplied with the principal plant foods. The Kaeleku soils are notably higher in lime content and also contain more acid soluble potash. Field experiments should be installed in both portions of the plantation owing to the differences in climatic conditions and soil composition.

Waimanalo Sugar Company

Our results showed some fairly consistent differences in the composition of these typical soils. The samples were in general well supplied with plant food, but two fields were found to be low in available phosphates and two others in available potash. Field trials are being planned by the agricultural department so as to coordinate these results with actual cane yields.

One group of fields appears to be quite high in all forms of plant food. Here experiments are being laid out to compare the effect of using nitrogen alone, against that obtained with mixed fertilizers. This is in line with the policy of attempting to obtain the greatest possible fertilizer economy, without decreasing the yields of sugar.

We determined the salt content of the samples from the lower fields where there might have been some accumulation of salts from the irrigtaion water. None of the samples contained sufficient soluble salts to be in any way harmful to crops.

An increased water supply is probably the most pressing need of the Waimanalo plantation. We determined the hygroscopic coefficients and maximum moisture holding capacity upon all the samples of soil. Our results showed a good water holding capacity in all the samples. We have therefore recommended that an attempt should be made to use this capacity of the soil for water storage by winter irrigation of the drier fields, between rains, when surplus water is available. This would enable all the fields to start the summer season of probable water shortage with some reserve of moisture.

Pioneer Mill Company

A wide variation occurs in the types of soil included in the plantation's 10,700 acres of cane land.

Fields were selected in each section of the plantation, so that samples were taken from all the important types of soil. Our analyses of these samples showed that a group of the new fields were notably low in available phosphates. Another set of fields contained intermediate amounts of phosphates, while the balance of the plantation appeared to be well supplied with both total and available phosphoric acid.

Messrs. Walker and Glick have made some interesting determinations of the phosphoric acid in the juices of the cane from part of the fields harvested during the past grinding season. We sampled the soil from some of these same fields and found an excellent agreement between the results by both methods on judging the fields that are high in available phosphate. The field that would be classed as intermediate and low by the two procedures do not agree so well, but there is sufficient relationship so that it is desirable to obtain more information on the phosphate content of the juices. Field trials should also be made on areas that are classed as low by one method

and not by the other. Nearly all the fields sampled were fairly well supplied with available potash, and have satisfactory amounts of strong acid soluble and total potash.

This work points out several suitable areas for experimentation with phosphates and potash. Water is at present one of the greatest limiting factors in the production of larger crops of cane. In years of plentiful water supply, when irrigation water can be supplied to fields at ten to twelve day intervals, we have suggested that larger applications of nitrogen may profitably be made.

Koloa Sugar Company

The soils of this plantation are being studied to assist the plantation in learning if distinct differences in color and texture of soils are associated with deficiencies of any of the principal plant foods. The work further bears upon determining the proper location of field experiments in connection with fertilizer requirements.

Progress in Soil Research

Important researches bearing upon Hawaiian soils and their behavior under heavy fertilization, have been conducted by Mr. Stewart and Mr. McGeorge. The work covers soils from the four islands of the group and offers evidence that we have much to gain through soil analyses. Mr. Stewart's report gives the following account of the work:

The results indicate that with the present island agricultural practices, that is to say essentially a one crop system of agriculture, soil analyses may be used to considerable advantage in developing our knowledge of fertilizer requirements.

Determinations of total phosphoric acid by fusion, and citrate soluble phosphoric acid, appear to be of the greatest value. The results would, however, indicate that regardless of the method used, higher figures will be obtained from those soils giving no response to phosphate fertilization than from those that do respond. The analyses of the soils have shown a range of 0.0009 per cent to 0.319 per cent P_2O_5, soluble in 1 per cent citric acid. The range of total phosphate by fusion varied from 0.17 per cent to 1.17 per cent P_2O_5. The citric acid soluble P_2O_5 in soils responding to phosphates varied from 0.0009 per cent to 0.0027. The citric acid soluble P_2O_5 in soils giving no response varied from 0.0026 to 0.319 per cent.

Acidity of soils responding to phosphates Ph. 4.6 to 6.3.

Acidity of soils not responding to phosphates Ph. 6.1 to 8.2.

Forms of Lime: The soils giving no response to phosphate fertilization contain lime in a more soluble form than those that do respond.

Silica: In general, silica is more soluble in soils giving no response to phosphates.

The analyses so far obtained would indicate that a soil with 0.0025 per cent P_2O_5 or less, soluble in 1 per cent nitric acid, will, with rare exception, respond to P_2O_5 fertilization. Those soils with 0.0026 to 0.0045 per cent citric acid soluble P_2O_5 would be placed in the doubtful class. Fertilizer response in such cases appears to be

closely related to the total content of $P_2 O_5$ present in the soil. Soils containing more than 0.0045 per cent citric acid soluble $P_2 O_5$ will rarely respond to phosphate fertilization. A knowledge of the acidity, lime content and citric acid soluble silica will aid greatly in the interpretation of the analysis.

There does not appear to be any relation between the mechanical composition of the soil and the availability of the phosphates.

Effects of Soils of Saline Irrigation and Chemical Fertilization

A study of the soils of the Ewa Plantation Company, which have been subjected to saline irrigation and heavy applications of nitrate of soda for a number of years, compared with soils which have not been so treated, showed that no great change has taken place in the reaction of the field soils as a result of continuous irrigation and fertilization. This work was conducted on three soils of radically different types, one a red coral soil, the second a brown silty clay loam, and the third a heavy black clay adobe.

Further work in the fields at Ewa by Mr. Stewart tends to confirm his lysimeter experiments, showing that nitrates are largely retained in the second and third foot of soil, so that no no great loss occurs under ordinary conditions of cropping.

Effect of Borax on Sugar Cane

The presence of small quantities of borax in some of the fertilizing materials now on the market, and the damage from borax reported from the mainland on tobacco, cotton, potatoes and other crops, has caused us to investigate, for the Pacific Guano and Fertilizer Company, how sensitive sugar cane is to borax. Experiments by Mr. Stewart in concrete tubs have been conducted. He reports:

There was no noticeable injury to any of the cane which had received up to 250 pounds of borax per acre. The cane receiving 4,000 pounds of borax per acre was distinctly stunted, but is still sending out some new growth. Only traces of borax have been washed out of any of the soils in seven months' time.

Organizations for Work in Forestry

This Experiment Station is now administering three forestry units, for which funds have been subscribed by various interests.

Unit 1 is that of the Halawa-Niulii Reserve, 2,609 acres, and is supported by subscriptions from the following interests:

Estate of James Wight,
Kohala Sugar Company,
Estate of Chas. F. Hart,
Bernice P. Bishop Estate.

These funds are subscribed on the basis of the area of the forest reserve owned or controlled by each interest. Arrangements have been made whereby semi-annual subscriptions will be made so as to furnish funds for caretaking and reforesting operations at the rate of $3,064.80 per year.

Unit 2 is that of the Koolau Mountains, Oahu. This project is being supported through a second subscription by the plantations interested, $8,641.36, divided *pro rata* on the basis of their 1921 sugar production. These plantations are:

Oahu Sugar Company, Ltd.,
Waialua Agricultural Company, Ltd.,
Ewa Plantation Company,
Apokaa Sugar Company, Ltd.,
Kahuku Plantation Company,
Koolau Agricultural Company, Ltd.,
Honolulu Plantation Company,
Laie Plantation.

It is felt that it is appropriate for this fund to be supplemented by subscriptions from the estates, individuals and corporations which own in fee simple the sugar lands that are to benefit from this reforestation. Of those interests which have been asked to participate in this work, subscriptions have been made by the following:

Queen Emma Estate,
J. W. Austin Heirs,
S. M. Damon,
J. S. Emerson.

The Bernice P. Bishop Estate has shown interest and is lending support in furthering the plan.

Unit 3 is that of the Hilo Reserve. This work is being carried forward by the original fund subscribed by the following plantations on the basis of their 1919 sugar production, the fund being $8,118.40. These plantations are:

Onomea Sugar Company,
Pepeekeo Sugar Company,
Honomu Sugar Company,
Hilo Sugar Company,
Hakalau Plantation Company,
Hawi Mill Company, Ltd.
Laupahoehoe Sugar Company.

We believe that interest is increasing in the preservation of the forest cover of the invaluable watersheds of these Islands. This will lead, we think, to the recognition by all of the responsibilities each shares in this work. The time is evidently at

hand when landowners and plantations are to enter into a co-operative endeavor with government interests to protect and improve forest cover, each interest bearing its due share of the expense involved.

Reforestation Activities

The work which the Station has conducted on Oahu, Maui and Hawaii has been handled by Dr. Lyon with the assistance of L. W. Bryan and George A. McEldowney. Dr. Lyon gives the following report on this work:

Oahu Project

Our records show that 126,064 trees were contributed by the Department of Botany and Forestry for planting on the Island of Oahu. The majority of these were planted by Mr. McEldowney in the Ewa Forest Reserve, while the balance were planted at his suggestion and, in most cases, under his personal direction, in waste lands and about camps on the plantations. He has received very valuable assistance in his work from the United States Army, which has planted out some 30,000 trees on the Government Reservation at points within, or adjacent to, the Ewa Forest Reserve. On May 28, Army aviators flew over designated areas on the Koolau Mountains, scattering fifty-three pounds of *Ficus macrophylla* seed, which we had delivered to them a day previous.

Further investigation of the forestry conditions on Oahu strengthens our conclusions, previously stated, that the forests on this Island are in a very critical condition and that their complete collapse over considerable areas may be expected at any time. The gradual depletion of these forests is converting them from compact rain forests into open woodlands, which dry out quickly during periods of drought. The danger of serious forest fires is, therefore, increasing from year to year. During the past year several disastrous fires have occurred.

The preservation of an adequate forest cover on the Koolau Mountains is so vitally important, not only to the agricultural interests on this Island but to every phase of industry in which this Territory as a whole is concerned, that no effort or expense should be spared to preserve what little native forest still remains; to reinforce this waning native forest with new and vigorous trees, and to create new forests over the large areas which have been so ruthlessly denuded.

Hilo Project

Due primarily to the unlimited energy and enthusiasm of Mr. L. W. Bryan, the Hilo Forest Reserve has, in the course of a litlte more than one year, been converted from a paper reserve, the boundaries of which were poorly defined and in many places quite unknown, to the best defined and best administered forest reserve on these Islands.

In this Forest Reserve, we have a considerable area on an important watershed still covered with a healthy forest, but experience teaches that this forest will remain healthy only in case that it receives ample protection from the inroads of stock and man. It is only at

this late date that adequate protection is assured. There is urgent need that the remaining native forest be strengthened on its margins and extended with new trees until a proper forest cover has been obtained throughout the length of the watershed.

In the Hilo Forest Reserve we have at all times worked in close cooperation with the Bureau of Agriculture and Forestry and recently Mr. Bryan has taken over for this Board the supervision of this Forest Reserve and is now armed with all of the powers and privileges of a government officer.

Among the important results accomplished during the past year the following may be mentioned here:

All boundaries not previously surveyed have been run out and properly marked. This includes the entire makai boundary which extends cross country, traversed with extreme difficulty.

Some 50,000 feet of new fence have been constructed at various points along the boundaries.

Over 29,000 trees have been planted out in the Reserve.

Large quantities of seed of Moreton Bay fig have been broadcast in partially denuded areas and very satisfactory results have been obtained through this procedure.

Kohala Project

Work in the Kohala district has consisted in patroling the Reserve, expelling all cattle found therein, repairing fences, clearing out about trees previously planted, and planting additional trees.

Forestry on Maui

The proposed project on West Maui has not been organized, but considerable tree planting on the watershed has been done by the Pioneer Mill Company and the Wailuku Sugar Company, each operating independently.

The East Maui Irrigation Company planted out in the districts traversed by their ditches over 30,000 fig trees of the three species, *Ficus macrophylla*, *F. rubiginosa*, and *F. henneana*. Mr. Pogue states that "the average cost of preparing the soil, planting and staking all of these trees was slightly under two cents per tree."

The Introduction of Fig Wasps

That the introduction of fig wasps into Hawaii is going to play an important part in our reforestation plans there now seems little doubt. Success has been attained through the work of Mr. Pemberton in making the Moreton Bay fig bear fertile seed, and there is also a reasonable chance that the work on the Port Jackson fig will be successful. As opportunity permits, it is hoped that arrangements can be made to continue this work and have the entomologists secure fertilizing insects for other valuable members of the genus *Ficus* which thrive in Hawaii.

From Mr. Sweezy's report we read:

The species (*Pleistodontes froggatti*) which is associated with the

Moreton Bay fig and which was introduced from Australia in 1921 and became established on the tree in Emma Square, Honolulu, continued to increase in its successive broods, with a corresponding increase in production of fruit and seeds on this tree. The wasp has also become established on a large Moreton Bay fig on Nuuanu Avenue, and both of these trees have yielded a considerable amount of seed for planting. Colonies of the wasps have been transferred to other trees wherever known to occur.

Another species (*Pleistodontes imperialis*) which is associated with the Port Jackson fig, was received from Australia in January, 1922, sent from Sydney by Mr. Pemberton. Large numbers of the insects issued from the material received and were liberated on the trees available. In July, ripening figs were found containing living fig-wasps, demonstrating the establishment of this insect. If it succeeds in increasing in succeeding broods as *P. froggatti* has done, these trees of the Port Jackson fig will soon be yielding seeds for planting.

Thus the wasps for two kinds of *Ficus* trees have been introduced and established, and there is reason to believe that other desirable ones may also be introduced if sufficient attention be given to it.

The Vineyard Street Nursery

Since the resignation of Mr. Holm in April, Dr. Lyon has given personal supervision to the work of the nursery, being assisted by Mr. McEldowney and Mr. Caum.

During the past year 244,083 trees were distributed from this nursery. These were divided among the different islands as follows:

Oahu	126,064
Kauai	131,678
Hawaii	192,283
Maui	51,600
Molokai	200

A more detailed tabulation of this distribution appears in the appendix of this report.

Dr. Lyon reports the stock of the nursery as of September 30 to include "a little more than 100,000 trees of suitable size for immediate planting, but in addition, we have on hand a very large stock of young seedlings, which will be ready for distribution during the coming winter months." He is giving special attention to the Moreton Bay fig grown from local seed, and is having his men collect and prepare the seed from the two trees in Honolulu which have been caused to bear viable seed.

Manoa Arboretum

The lands which we have recently acquired in upper Manoa Valley, partly through purchase and partly on leases at nominal rentals through the generous cooperation of the Bernice P.

Bishop Estate, and the Honorable George R. Carter, will, without doubt, prove to be an interesting and valuable asset to the forestry work of this Station and to that of the Territory at large. Dr. Lyon reports the following information:

During the year just closed, 873 trees, representing 172 species, were planted out in the Manoa Arboretum, principally upon the lands leased from the Bishop Estate.

Mr. Caum has taken a census of the trees planted out in the entire Arboretum and has prepared a species and position index which enables us to determine the number of specimens of each species planted and the exact location of each specimen.

The Fern Weevil Parasite

The work of maintaing a suitable forest cover on the watersheds of these Islands will be materially assisted through the fact that a parasite has now been successfully established upon the fern weevil which has done much damage to the *Sadleria* ferns of Oahu and the region about the volcano. Concerning this, Mr. Swezey says:

This parasite (*Ischiogonus syagrii*) was introduced by Mr. Pemberton in 1921 from New South Wales, where he discovered it in the Richmond River district. It has now become well established on Mt. Tantalus, Oahu, and at Kilauea, Hawaii, where the fern weevil was known to occur. The latter place was visited by Mr. Pemberton August 6, about a year from the time when the parasites were first liberated. The parasites were found well established. At all points where the weevil had spread, either the living parasites larvae were found, or their pupae or cocoons in the hollowed-out fern stems where the weevil larvae had fed. It is yet too soon for the parasite to have reached its maximum of efficiency, but the weevil is being checked in its spread already. No doubt complete control will soon be effected and the weevil prevented from menacing the natural fern growths of the forest cover on the watersheds of Hawaii.

From the experience on Mt. Tantalus, where the fern weevil gradually spread, leaving in its wake no living *Sadleria* ferns, it is to be inferred that it would have spread, if remaining unchecked, through the entire forests of Hawaii, killing all of this fern which is recognized as an important component of the natural forest cover. To accomplish the control of this weevil and check its spread by the introduction of its special parasite, is to be considered a noteworthy achievement in forest protection.

An Experiment in Planting Forests by Airplane

Through the cooperation of Major-General Charles P. Summerall, commanding the Hawaiian Department, U. S. Army, a trial was made of the possibilities of rehabilitating the forest cover of these islands by sowing seed from an airplane. This

experiment may be of far-reaching importance, for the rapidity and ease with which the areas of a watershed can be covered in this way so far exceed what can be done through the ordinary methods of planting trees, that work that might otherwise take generations to accomplish is reduced to a matter of a comparatively brief time. C. S. Judd co-operated in the experiment by permitting certain areas of government forest land to be used for the purpose, and in getting the permission of other interests who control adjoining areas. The seed used in this test was obtained by Dr. Lyon from the Moreton Bay fig tree in Emma Square, Honolulu. This tree, growing there for many years, had recently been caused to produce fertile seed through the introduction of the pollinating insect from Australia by Mr. Pemberton. The Moreton Bay fig is a tree recommended by Dr. Lyon and endorsed by the Board of Agriculture and Forestry as a desirable one for watershed cover. It furthermore offers promise of being propagated through falling seeds becoming lodged in suitable places, such as those offered by the decaying wood of fallen trees, dead branches, and the like. The area picked for this work was one where many dying forest trees presented the right conditions. The seed was sown in May on the lower edge of the forest of the Koolau Mountains.

Pineapple Investigations

The increased amount of work on pineapples which the Station has undertaken for the Association of Hawaiian Pineapple Canners made it advisable for this work to be organized as the Pineapple Department. This work is headed by Dr. Lyon, who represents the Station in handling the work which we have contracted to perform. Dr. Lyon reports work of the past year as follows:

Breeding

Over 6,000 seedling varieties of pineapples have fruited in our cultures. By following the behavior of these varieties very carefully and keeping careful records of their performances, we have obtained data which enables us to select promising varieties with some degree of certainty that they will maintain the rank which we ascribe to them.

It is a very simple matter to grow pineapple seedlings, but an extremely difficult matter to isolate the exceptionally good from the average varieties. It is, of course, a simple matter to eliminate the poor varieties which are certain to predominate in any culture of seedling plants. Our studies of reproduction in the pineapple plant and our records of the performance of fruiting seedlings indicate that real progress in the development of new varieties can be attained

only through careful breeding brought about by the hand pollination of the pineapple flowers. The spontaneous production of seed by pineapples under local conditions indicate abnormalities in the plants producing this seed. We have, therefore, abandoned the planting of chance seed obtained from the canneries.

We now have in our cultures some ten standard varieties which are cultivated in various parts of the world and we are making all possible crosses between these in our breeding experiments. During the past summer, we secured over 39,000 seed from fruits, the flowers of which were hand pollinated last winter.

Selection of Superior Strains

In order to secure data on which to base a selection of the superior strains in Smooth Cayenne, we have staked off small blocks in two fields of pineapples and are keeping performance records of each individual plant in these blocks which contain a total of over 12,000 plants. We are also selecting and marking plants throughout the pineapple fields which appear to be superior to the general run. Propagating material from these plants is being segregated in our cultures, each plant being given a distinctive number. This work is being handled by Messrs. Doty and Denison.

We find that in all of our pineapple fields there occur two very distinct types of fruit, which are decidedly inferior to the normal type. If our experiments show that these types are actually distinct strains, the average yield in our pineapple fields can be materially increased by the elimination of these inferior types.

Field Experiments

With our augmented staff we have been able to increase the scope of our field experiments which now deal with fertilizers, methods of culture and application of sprays.

We are devoting eleven acres at Kapalama to field experiments with Smooth Cayenne. An additional area of one hundred acres has just been secured at Wahiawa to permit of the extension of our field work.

Pineapple Pathology

Work in the study of pineapple diseases is reported upon by Dr. Lyon as follows:

Root-rot

Field observations and experiments, together with the laboratory investigations conducted by Mr. Carpenter, Dr. Kunkel and the writer lead us to the following conclusions regarding Pineapple Wilt:

Pineapple plants are subject to the attacks of parasitic fungi which induce the symptoms known as Wilt, but in addition to this cause, there are other factors which may produce the same symptoms.

The root-knot nematode has, in restricted localities in our pineapple fields, reached such concentration as to bring about the destruction of all of the roots of the pineapple plants and cause these to wilt as a result. Many cases have come under our observation where the pineapple plants over considerable areas have wilted because the

soil in which they were growing became water-logged during the rainy season.

Heart-rot

A pineapple disease which causes rather serious losses in fields of young plants during the cool and rainy winter weather has been designated "Heart-rot."

As the name indicates, this malady is characterized by the decay of the growing point and tender leaves emanating therefrom. While the decay usually starts from the center of the plant, it progresses outward through the tender bases of the older leaves and, in extreme cases, may cut off all of the leaves. As a rule, however, decay stops before it reaches the outer leaves. In the early stages of the disease, the plants look quite normal. Then the central leaves, which are usually upright, tip over to one side. At this stage, it will be found that all of the central leaves may be lifted out because they have all been cut off at their bases.

In our early studeis, we attributed this disease to the activities of a phycomycetous fungus, which we provisionally referred to the genus

Phytophthora.

During the winter of 1921-22, this disease appeared in an exceptionally virulent form in certain pineapple fields at high elevation on this Island, and while studying the disease, Dr. Kunkel succeeded in isolating this phycomycetous fungus in pure culture and in producing the disease in healthy plants by inoculating it into their tissues. Dr. Kunkel has been conducting extensive experiments designed to control this malady by means of fungicidal sprays.

Chemistry Work on Pineapple Problems

The chemistry department has also contributed to the work on pineapple problems. E. C. Thomas has handled the analytical work under Mr. Stewart, who reports upon the work as follows:

We have received miscellaneous samples of waters, stock feeds, soils, ferrous sulfates, insecticides, and fertilizers. Besides this work an extensive study of nitrification was completed early in the year. We have carried on further investigation of several cannery problems.

Our most extensive investigation is a study of the composition of the pineapple plant at different stages of growth. This work is planned to give us information as to the storage of nutrients by the pineapple plant throughout its life cycle, starting with the young crown. It will extend over another season or more before a complete set of results is obtained. We are sampling the plants at three month intervals, dating this period from the time the crowns started to grow. This study has considerable interest from the point of view of fertilization and plant nutrient. It will also furnish us with a standard of comparison as to the changes which take place in the pineapple plant when it is affected by wilt. We have analyzed one set of wilt plants of an age of 10 to 12 months and a similar group

of healthy plants. The most striking difference found was in the nitrogen and sulfur content. The average content of nitrogen in healthy plants was 1.51 per cent, while the average nitrogen in the wilt plants was 1.13 per cent, these results all being on the water free basis. The average sulfur content of the healthy plants was 0.17 per cent, while the wilt plants only contained 0.07 per cent.

It does not follow, in plant nutrition, that a deficiency can be directly supplied by the addition of the missing element. I should, however, recommend as a trial measure that varying applications of ammonium sulfate should be applied to the soil and to the leaves as a spray for the treatment of wilt.

Miscellaneous Crops and Plants

The following work on crops other than sugar cane and pineapples is covered in a report by Dr. Lyon:

A Disease of Bananas

At the request of the owner, Dr. Kunkel visited a banana plantation at Mokuleia and Kawaihapai during May to examine plants suffering from a curious malady. The diseased plants showed symptoms suggesting Mosaic, but Dr. Kunkel found bacteria present in large numbers in the diseased tissues and is inclined to consider these organisms the cause of the disease.

A Guava Disease

During a trip through Kona, I visited some ranch lands above 2,000 feet elevation in Kealakekua, which have for years been covered with a dense growth of guava. At the present time, the guava bushes over a considerable area are afflicted with a disease which at some points has killed all of the plants. An examination of the afflicted specimens in the field and a careful study of material brought back to our laboratory in Honolulu show that the plants are being attacked by a fungus which kills all new growths shortly after these appear. When one set of new twigs is killed back, the plant produces another set which is in turn killed back, this succession of events apparently continuing until the plants actually die of exhaustion.

Jack Bean Mutations

During the past summer, Mr. Caum has grown another generation of our mutating Jack beans, which has resulted in the appearance of several new and distinct varieties. We now have no less than sixty distinct seed varieties, which have been derived from the common white-seeded Jack bean. Our Canavalia cultures afford one of the most remarkable examples of spontaneous mutations known to science, and it is most unfortunate that the problem cannot receive the attention which it deserves, for its elucidation would be an extremely valuable contribution to the science of plant breeding and the problem of the origin of species.

Bulletin on Lantana Insects

A manuscript has been received from Dr. R. C. L. Perkins giving a complete account of the work of A. Koebele and himself on the introduction of insects injurious to lantana. This has been supplemented by an article by Mr. Swezey, who gives an account of the present status of lantana and the insects which feed upon it. This work has an important bearing upon economic entomology in that it is the most important, if not the only, case where noxious vegetation was put under partial control through the introduction of its insect enemies.

The Experiment Station Committee is of the opinion that these papers should be published at some opportune time.

Nut Grass Enemies

The spread of nut grass in the fields of many plantations and the appeal to the Station for assistance in suppressing it, has caused us to investigate, through Dr. Williams, the natural enemies of this weed which occur in the Philippines. Great caution is being taken in releasing any insects which feed upon vegetation, and material which has been brought to Honolulu has been used for experimental purposes under quarantine. Mr Swezey reports on this work as follows:

When Dr. Williams returned from the Philippines in April of this year, he brought two kinds of insects which were found attacking nut grass in the Philippines. Both of these insects are stem borers, their larvae boring down the setm, entering the underground "nut," or corn, and feeding therein, destroying it. One of these insects is a weevil or snoutbeetle somewhat related to the cane borer, and closely related to bill-bugs occurring in the States, where several species are known to attack corn, grasses, sedges, etc. The other is a Tortricid moth related to one already in the Islands and boring the stems of sedges in the mountains. Instead of liberating these insects, it was considered best to experiment with them in quarantine and ascertain whether they would attack other plants or crops. It was found that they bred on nut grass in cages. They were tried similarly with cane, corn and pineapples, and in every case failed to attack these plants. Attempts to breed them on the umbrella plant, an ornamental sedge, also failed. These experiments finally practically exhausted the stock, as always all were lost that failed to breed on any plant with which they were tried. The experiments would indicate that it would be safe to introduce these insects as enemies to nut grass. However, not much could be expected of them, for Dr. Williams found only about 5 per cent of the nut grass killed by them in the Philippines.

Miscellaneous Introductions of Beneficial Insects

Several introductions of beneficial insects on crops other than cane are reported by Mr. Swezey as follows:

Cricket Parasite

A small colony of a Larrid wasp, parasitic on the field cricket. Sent from the Philippines by Dr. Williams. Liberated at the Experiment Station grounds.

Bean Butterfly Parasites

A small colony of Ishneumonids, parasitic on the larvae of the bean butterfly. Also two kinds of wasps which prey on these caterpillars. Brought from the Philippines by Dr. Williams.

Looper Caterpillar Parasite

A small colony of a parasite (*Euplectrus*) attacking looper caterpillars. Brought from Hong Kong by Dr. Williams. Liberated at the Experiment Station grounds.

Publications

The Record, heretofore issued monthly, was made a quarterly at the beginning of 1922. This new arrangement has been a satisfactory one.

The Commercial Sugar Report, dealing with the quality of grain of Hawaiian raw sugars, was discontinued after the close of the 1921 crop.

Various members of the staff have contributed articles to scientific journals. The work of Messrs. Swezey, Muir and Timberlake in contributing to the Proceedings of the Hawaiian Entomological Society, the Proceedings of the U. S. National Museum, the Philippine Journal of Science, and other publications, has placed some of our entomological work before other investigators engaged along similar lines.

Additions and Changes of Staff

Through the death of John F. Melanphy in December, the Experiment Station lost a valuable member of its staff.

E. D. Merrill, Director of the Bureau of Science, Manila, who had agreed to join our staff as Systematic Botanist, found it inadvisable to leave his post in the Philippine Islands.

J. H. Midkiff resigned as Associate Agriculturist in August to accept a position with the Koloa Sugar Company.

R. S. Thurston retired from his position as Associate Agriculturist on account of the condition of his health.

C. W. Carpenter resigned as Associate Pathologist in October to enter business in Honolulu.

Adolf Holm, Superintendent of Forest Nurseries, resigned his position in April to engage in work in California.

W. R. R. Potter, who held the position of Illustrator for many

years, resigned in April to engage in illustrating work in San Francisco.

G. B. Grant resigned as Assistant Agriculturist in July to accept a position with the Hawaiian Commercial and Sugar Company.

W. C. Jennings has been engaged as Assistant Agriculturist and assigned to work in Hamakua and Kohala.

O. C. Markwell has been engaged as Assistant Agriculturist and assigned to work on Kauai.

H. L. Denison was transferred from the Agricultural Department to the Pineapple Department in January.

H. T. Osborn, whose services were transferred temporarily to the Board of Agriculture and Forestry, for entomological work, has been absent throughout the year.

W. A. Wendt joined the staff as Assistant in Pineapple Investigations in February.

W. J. Bryant resigned as Assistant in Pineapple Investigations in August.

C. E. Warriner, Assistant Chemist, resigned in January.

Respectfully submitted,

H. P. AGEE,
Director.

APPENDIX

Laboratory Work

Statistics bearing upon the work of the chemical laboratory are given as follows. In handling that part of the work which pertains to his department, Mr. McAllep was assisted by Messrs. W. L. McCleery, A. Brodie, H. F. Bomonti, and H. A. Cook. In the chemistry department, Mr. Stewart was assisted by Messrs. W. T. McGeorge, W. R. Werthmueller, E. C. Thomas and Fred Hansson.

Sugar Technology Department

Instruments and Apparatus		
Analytical weights standardized	1	
Brix hydrometers calibrated	471	
Flasks calibrated	11	
Pipettes calibrated	2	
Polariscopes cleaned and adjusted	4	
Polariscope tubes tested	6	
Refractometers examined	1	496
Miscellaneous Analyses		
Bagasse paper analyses	2	
Cane juice analyses	2	
Cast-iron drillings	3	
Fuel oil	105	
Furnace ashes	8	
Massecuites	9	
Molasses	128	
" for K_2O	11	
" thermal value	1	
" ash analyses	5	
Press cake	1	
Sugar analyzed (commercial)	104	
" " (low grade)	2	
" " for insoluble solids	21	
" " for polarization	97	
" " for grain separation	212	
" " for salt determination	2	
" " for micro-organism count	5	
Superphosphate	1	
Urine-polarization	1	720
Cane juices—for other departments		
Makiki plots	1,457	
Waipahu	78	
Waipio	17	
Waialua	13	
Alexander Street plots	10	1,575
Determinations in Research		3,492

Chemistry Department

Fertilizers		
Complete fertilizers reported	210	
Agents' reserve samples	5	
Nitrate of soda	1	
Potash nitrate	46	
Potash salts	3	
Sulfate and nitrate mixtures	15	
Superphosphates	1	
Repetitions	85	366
Miscellaneous		
Ammonium nitrate	2	
Ammonium sulfate	3	
Ashes, mill	7	
Ashes, molasses	2	
Bagasse	1	
Blood, dried	2	
Cane juice	1	
Deposit from piston heads	1	
Fertilizers	11	
Formaldehyde	2	
Lime, hydrated	1	
Molasses	3	
Nitrate of soda	3	
Phosphate rock	2	
Potash, chloride	1	
Potash, crude	1	
Potash, salts	5	
Potash nitrate	1	
Potash sulfate	3	
Press cake	4	
Scale deposit	1	
Superphosphate	1	
Waters	19	
White residue from galvanized iron	1	
Yellow crystals from steel	1	
Zinc paint, white	1	
Zinc oxide	1	81
Pineapple Work, Miscellaneous		
Including waters, fertilizers, ferrous sulfate and miscellaneous factory samples		34
Pineapple Work Investigations		
Soils, nitrification, plant analyses		1,370
Chemical Work Investigations		
Determinations on research problems		9,244
TOTAL		17,378

Fertilizer Control Work

An account of the work during the past year in checking the compositions of fertilizers shipped to the plantations is given by Mr. Stewart as follows:

During the past year, 273 fertilizer samples, representing 19,381½ tons have been analyzed in our inspection work. Of these samples, 213, representing 12,609¼ tons, were sampled in Honolulu, and 60, representing 6,772¼ tons, were sampled by our agents in San Francisco. The samples handled were somewhat smaller in number than last year, which was due to the unusual number which fell below the guarantee.

There were 45 samples deficient. These samples showed an indicated rebate of $6,932.12. Of these samples, 32 were from Honolulu with a rebate of $3,002.50 and 13 from San Francisco with a rebate of $3,929.62. The Honolulu samples represented 1,795 tons and the San Francisco 1,552 tons. The number of samples deficient is exceptionally large and the cash value of the rebate is correspondingly appreciable.

DATA ON TREE DISTRIBUTION

Dr. Lyon shows the tree distribution from the Vineyard Street Nursery as per the following tabulated statement prepared by Mr. Caum:

Oahu—	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Tot.	
Ewa Pltn. Co	....	....	....	....	491	961	....	465	....	....	....	19	1,936	
Honolulu Pltn. Co	....	....	....	4,350	4,000	....	....	....	12.286	867	....	50	21,553	
Kahuku Pltn. Co	....	....	....	....	....	....	870	....	....	....	....	41	911	
Laie Plantation	....	....	....	....	....	....	....	....	....	958	....	....	958	
Oahu Sugar Co	4,960	....	713	255	34	685	....	....	25	....	....	25	6,697	
Waiahole Water Co	....	....	....	....	....	....	....	850	....	....	....	....	850	
Waialua Agr. Co	....	....	....	....	....	....	....	....	....	....	1,333	8,989	10,322	
Wahiawa Nursery	1,200	....	2,437	3,891	....	5,574	....	170	3,956	6,195	18	5,284	31,725	
U. S. Army	....	1,692	14,670	....	5,535	....	....	1,872	3,780	....	....	146	27,695	
Pineapple Interests	....	....	....	5,374	....	....	....	....	2,730	....	....	....	8,104	
Territory	....	....	....	383	....	96	3	....	70	295	....	250	1,097	
Miscellaneous	....	....	....	....	....	....	....	....	....	....	14,000	216	14,216	126,064
Kauai—														
Kilauea Sugar P. Co	....	....	1,000	5,000	....	....	....	....	....	....	....	....	6,000	
Miscellaneous	....	....	200	200	110	....	....	....	....	104	....	....	614	6,614
Hawaii—														
Hakalau Pltn. Co	....	....	1,500	500	....	....	....	....	....	....	....	....	2,000	
Hamakua Mill Co	....	....	500	500	500	....	....	....	....	....	....	....	1,500	
Hawaiian Agr. Co	350	....	1,000	2,000	50	....	1,000	1,982	....	....	....	....	6,382	
Hilo Sugar Co	....	....	....	500	....	....	....	500	....	1,000	....	....	2,000	
Honokaa Sugar Co	....	....	1,500	1,500	1,000	1,000	250	....	....	....	....	....	5,250	
Honomu Sugar Co	....	....	500	500	....	....	....	....	500	1,000	1,500	2,000	6,000	
Hutchinson S. P. Co	....	....	300	....	....	....	....	....	....	....	....	50	350	
Kohala Sugar Co	....	....	....	300	....	....	....	....	....	....	....	....	300	

Laupahoehoe Sugar Co	....	....	500	....	500	....	....	....	....	....	....	....	1,000	
Paauhau S. P. Co	....	....	....	500	....	....	....	....	....	....	....	....	500	
Pacific Sugar Mill	....	....	....	1,000	1,000	1,000	250	....	....	....	....	....	3,250	
Hawaiian Irrig. Co	....	....	....	....	....	....	200	500	400	100	....	100	1,300	
Parker Ranch	....	....	2,000	4,858	4,000	....	....	....	....	....	....	....	10,858	
Bryan, L. W	100	500	510	2,000	1,139	....	....	5,001	4,500	2,100	2,601	....	18,451	
Miscellaneous	....	....	....	....	268	86	100	10	....	....	....	....	464	59,605
Maui—														
Kaeleku Sugar Co	....	....	200	800	800	800	800	1,000	200	....	....	....	4,600	
Pioneer Mill Co	....	....	....	5,000	4,000	4,000	....	....	....	....	....	....	13,000	
Wailuku Sugar Co	....	....	....	1,523	....	....	....	50	....	....	....	640	2,213	
East Maui Irrig. Co	....	....	500	3,500	4,000	4,000	4,000	5,000	3,500	5,000	2,000	....	31,500	
Miscellaneous	....	....	....	....	....	....	....	....	100	....	....	187	287	51,600
Molokai—														
Cooke Estate	....	....	....	....	....	200	....	....	....	....	....	....	.....	200
														244,083

SUMMARY OF YIELDS: WAIPIO SUBSTATION EXPERIMENTS, 1922 CROP

Experiment or Section	Gross Area	Variety	Growing Period		Age (Months)	Yield Per Acre			T.S.P.A. Per Mo.
			From	To		Cane	Q. R.	Sugar	
Long Ratoons									
J	6.51	H 109	6/15/20	4/22/22	22	102.99	7.24	14.23	.647
K	1.55	H 109	6/15/20	4/22/22	22	103.62	7.24	14.31	.660
L1	7.41	H 109	5/15/20	3/18/22	22¾	116.70	7.92	14.60	.642
L2	1.94	H 109	5/15/20	3/18/22	22¾	117.09	7.99	14.65	.644
M	3.44	Mixed Varieties	1/15/20	3/10/22	25¾	88.00	8.93	9.87	.383
O	2.02	H 109 D 1135	9/20/20	2/ 8 /22	16½	79.93	9.13	8.75	.529
P	3.03	H 109	8/28/20	6/15/22	21½	91.40	7.93	11.53	.536
R	4.04	Mixed Seedlings	9/14/20	5/15/22	20	71.82	7.54	9.52	.416
21	6.26	H 109	8/20/20	3/ 4 /22	18½	87.86	8.90	9.87	.534
28	8.42	H 109	9/30/20	6/21/22	20¾	82.25	7.43	11.07	.533
40	0.33	H 109	6/29/20	3/22/22	20¾	82.57	8.11	10.18	.491
Short Ratoons									
F	2.57	H 109	5/27/21	8/16/22	14½	67.98	7.36	9.23	.636
G	1.89	H 109	4/25/21	8/12/22	15½	75.38	8.66	9.13	.589
H	1.23	H 109	4/14/21	8/10/22	15½	79.81	7.80	10.23	.660
Plant Cane									
Q	1.44	H 109	9/ 5 /20	6/22/22	21½	82.87	8.07	10.27	.478
26	11.95	H 109	6/29/20	4/11/22	21½	94.70	7.79	12.16	.566

True Average

Kind	Gross Area	Age (Months)	Total Cane	Tons Sugar	Per Acre			T.S.P.A. Per Mo.
					Cane	Q. R.	Sugar	
Long Ratoon	44.95	20.9	4,224.34	534.86	93.98	8.13	11.90	.569
Short Ratoon	5.69	15.0	415.30	53.55	72.99	7.75	9.41	.627
Plant Cane	13.39	21.3	1,251.17	160.24	93.44	7.82	11.97	.562
Total or Avg.	64.03	20.5	5,890.81	748.65*	92.00	8.03	11.69	.570

* This includes 5.88 tons sugar from fire loss.